THE DESERT LOCUST IN INDIA

Mnnograph No. 21

ICAR 10.21
505

THE DESERT LOCUST IN INDIA

By

Y. RAMCHANDRA RAO M.A., F.R.E.S., F.A.Sc.
LOCUST RESEARCH ENTOMOLOGIST (RETD.)
INDIAN COUNCIL OF AGRICULTURAL RESEARCH

PUBLISHED BY
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

Price Rs. 73·50 *or* 111 *sh.*

FIRST PRINTED JANUARY, 1960

595.72600954
RAM

U. A. S. BANGALORE
UNIVERSITY LIBRARY.
28 JAN 1974
ACC NO. 4638
CL. NO.

Edited by U. N. Chatterji

PRINTED IN INDIA BY THE GENERAL MANAGER, GOVT. OF INDIA PRESS, NEW DELHI AND PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI, 1960.

PREFACE

A detailed scheme of investigations on the Desert Locust in its breeding grounds in north-western India was in progress under the auspices of the Indian Council of Agricultural Research, New Delhi, from December, 1930 till end of March, 1939. After its closure, part of the duties performed by its staff in respect of vigilance in the desert areas was taken over by the Locust Warning Organization created by the Government of India. As it was important that the scientific results obtained under the above scheme of locust research should be properly studied and written up, the writer was relieved of the charge of the scheme early in February, 1939, and placed on special duty at New Delhi with a small staff to help him in this work. It was then tentatively estimated that a consolidated account of the results could be presented in about nine months, but as the drafting of the report progressed, it became clear that, in view of the immensity of effort needed for a proper study of the great mass of results and of the necessity of consulting literature, records and collections at every stage of the work, progress could not be as rapid as contemplated. Actually, the writer was able to hand over his report on Part I of the monograph (containing the results of field investigations on the solitary phase of the locust) only on June 30, 1941, 3 months after his retirement from service.

In the course of the progress of the locust research scheme, a great mass of information on the activities of swarms during past locust outbreaks in India had been collected. A great part of the above data had been analysed, chronologically arranged under successive years in the different provinces and printed in 1940 by the Council for purposes of record of reference. As however, the value of the above data could not be assessed until they were studied in correlation with all available meteorological records and a connected account of past locust outbreaks in India was prepared. A scheme for writing this up as Part II of the monograph was sanctioned by the Council in July, 1942 and the writer was invited in October, 1942 to undertake this task. For various reasons, however, work could not be commenced earlier than May, 1944 and the complete report on Part II, accompanied by appropriate maps and statements, was ready for presentation only in October, 1945.

Although Part I of the monograph had been recommended for immediate publication, the Government had, in view of the exigencies of the war situation in 1942, to postpone it till after the end of the global conflict. At the suggestion, however, of Dr. B. P. Uvarov, Director, Anti-Locust Research Centre, London, excerpts from some sections of the report were permitted by the Council to be published in the December, 1952 issue of the *Bulletin of Entomological Research, London,* so that some of the main findings of the work done in India might be available for reference to other workers on the locust problem in and outside India.

By the time Part II of the monograph was submitted, the European phase of the war had ended. Early in 1946, the Pacific phase of the World War also came to a happy end, but owing to the continuance of paper shortage, there was apparently no easing up of the situation in respect of a resumption of publication work.

In August, 1946, the services of the writer were requisitioned for temporary re-employment as Deputy Director (Foreign Quarantines) in the Directorate of Plant Protection, Quarantine & Storage at New Delhi; and during his stay at Delhi, he made a representation through the Plant Protection Adviser to the Government of India, to the Indian Council of Agricultural Research, in April, 1947 urging the need for an early publication of the report. After mature consideration, the Council communicated, in May, 1948, its decision that before the monograph could be taken up for publication, the text should be revised and brought up-to-date and that Parts I and II should be welded to form a single publication of considerably reduced size. The writer undertook this task during his stay at Delhi, but by the time he relinquished his post in February, 1949, only part of the task had been done. In order to complete the work of revision and for preparing afresh four of the graphs (which had been lost during storage in the Council), he stayed on at Delhi till April 7, 1949, when he handed over the retyped text and the illustrations to the Editor.

The manuscript of the book was sent to the press in 1951 and work was briskly progressing, but due to an unexpected mishap, the printing had to be suspended and the material had to be composed afresh. This has resulted in an abnormal delay in the publication of the book, which is greatly to be regretted. In this connection, the writer wishes to express his gratefulness for the invaluable help received from Dr. M. S. Randhawa, Vice-President, Indian Council of Agricultural Research, New Delhi and Dr. B. N. Uppal, Agricultural Commissioner with the Government of India, in expediting in the recent past, the progress of printing at the Government Press.

The writer takes this opportunity to thank Mr. F. M. DeMello, the Editor of the Indian Council of Agricultural Research in 1941 for help given in the selection of photographs for use in the monograph and for various helpful suggestions, and his successor, Dr. U. N. Chatterjee, for help provided in the preparation of the new graphs and also for much advice in compiling lists of illustrations.

He also wishes to place on record his humble appreciation of the uniformly kind consideration received, while piloting the locust research scheme, from (the date) Diwan Bahadur Sir T. Vijayaraghavacharya, K.B.E., (the late) Sir Bryce Burt, C.I.E., M.B.E., I.A.S., and (the late) Sir Pheroze Kharegat, C.I.E., I.C.S. He would also signify his gratefulness for much consideration shown to him by Sir H. R. Stewart, C.I.E., I.A.S., during the writing up of Part II and by Sir Datar Singh, Kt., during the revision of the monograph. The writer wishes to express his thankfulness to Dr. W. Burns, C.I.E., D.Sc., formerly Agricultural Commissioner to Government, for help and advice in drafting Part I of the monograph. Last but not least, the writer wishes to place on record his sense of deep appreciation of the co-operation received from various colleagues and staff formerly engaged under the Council's locust research scheme in various investigations, for, although as head of the scheme, he had been privileged to write up a consolidated account of the work done, the subject matter of the publication is the combined result of patient and earnest team-work, in which all, including the writer, had given of their best.

Y. RAMCHANDRA RAO.

BANGALORE:
The 15th May, 1959.

ACKNOWLEDGMENTS

Administrative Help.—In the earlier days of locust survey work, when extensive touring had to be carried out in rather wild, sparsely, populated country, work was much facilitated by the provision of escorts or guides by the local authorities concerned, to whom the scheme is much indebted for the help received: Governments of Sind, Baluchistan, Rajputana, the Punjab, and the Western India States Agency; and the Durbars of Kalat, Lasbela, Kharan, Bikaner, Jodhpur, Jaisalmer, Jaipur, etc.

The Indian Council of Agricultural Research is also thankful to the authorities concerned in Sind, Kalat, Lasbela, Jodhpur, Jaisalmer and Bikaner for permission to open locust research stations at Chachro, Pasni, Ambagh, Barmer, Nokh and Sardarshahr respectively.

Meteorological Data.—The writer is greatly indebted to Dr. C. W. B. Normand, formerly Director-General of Observatories in India for much advice and help in respect of meteorological subjects and to successive Meteorologists at Karachi, Dr. S. K. Pramanik and Mr. V. V. Sohoni, for the supply of various publications and books on loan and of a large mass of data for past years. The writer is also thankful to Shri Ramachandra Aiyar, formerly Government Meteorologist, Bangalore, for loaning numerous volumes of Daily Weather Records of India relating to past years for study. Above all, he wishes to acknowledge the great assistance and advice received from Dr. L. A. Ramdas, then Agricultural Meteorologist, Poona, in connection with the setting up of meteorological stations and of various recording instruments.

Identification of Zoological Specimens.—Thanks are due to the Director of the Zoological Survey of India, Calcutta, for identifying various specimens of snakes, lizards, spiders and shells, to the Curator, Bombay Natural History Society, and to the Curator, Victoria Museum, Karachi, for identifying various specimens of birds.

Most of the insect collections were sent to the Imperial (now Commonwealth) Institute of Entomology, London, in batches and were received back with customary promptness, for which a debt of gratitude is due to the Director of the Institute. Many specimens were also named by the Imperial Entomologist, Pusa, during the earlier years. The writer is specially grateful to Dr. B. P. Uvarov, C.M.G., D.Sc., F.R.S., Director of the Anti-locust Research Centre, London, for much help and advice in the course of the investigations, especially during his visit to London in 1934, and for much helpful criticism in respect of the drafting of the present report, as also for editing some sections of the report in the *Bulletin of Entomological Research, London*, in 1942, as there was no prospect of its publication in India during the period of the war.

Identification of Plant Specimens.—Over one thousand sheets were sent to the Curator, Sibpur Herbarium, Botanical Survey of India, in successive consignments between 1932 and 1939, and the determinations furnished (since published as 'Miscellaneous Bulletin' of the I.C.A.R.—No. 43—1941) have been of invaluable help in the study of the ecology of the locust in its favourite haunts. Assistance received is gratefully acknowledged.

Study of Past Records for Extraction of Locust Data.—The writer wishes to place on record his thanks to (1) Superintendent, Madras Record Office, Madras, for permission to extract information on locusts from the printed Proceedings of the Board of Revenue and Government Orders of past years; (2) Director, Imperial Records Library (now Indian National Archives), New Delhi; and (3) Superintendent, Records Section, Mysore Government Secretariat, Bangalore, for permission to extract data on locusts for past years from various Gazettes. He is similarly grateful to Shri B. Krishnamurthy, then Mysore Government Entomologist, for loan of books and other help.

General Help.—The writer wishes to acknowledge his indebtedness to Dr. H. S. Pruthi, Ph.D. & Sc.D. (Cantab.), O.B.E., F.N.I., formerly Imperial Entomologist, for loan of books and provision of facilities for work in the laboratory, and for the execution of locust paintings by the Artist staff. His thanks are also due to the following for help rendered: Khan Bahadur Mian Afzal Husain for loan of Punjab data and for other help; Rao Bahadur Dr. B. Viswanath, formerly Director and Imperial Agricultural Chemist, Indian Agricultural Research Institute, for kindly arranging for the physical analysis of soil samples; and Dr. K. B. Lal, formerly Government Entomologist, Kanpur, for supply of locust data for the United Provinces.

Last but not least, the writer wishes to thank the various members of the former Locust Committee of the Indian Council of Agricultural Research in past years for their annual scrutiny of the results of the scheme and for general guidance periodically received.

Y. RAMCHANDRA RAO.

BANGALORE:
The 15th May, 1959.

CONTENTS

		Page
PREFACE		v
ACKNOWLEDGEMENTS		vii

PART I. STUDIES ON THE SOLITARY PHASE

SECTION I : INTRODUCTORY

Chapter I :	Genesis of Locust Investigations in India	1
Chapter II :	Review of Progress of Investigations during 1931 to 1939	5
Chapter III :	Cost of Scheme	11

SECTION II : GENERAL FEATURES OF THE INDO-IRANIAN REGION OF LOCUST HABITAT

Chapter I :	General Physiographical Features	13
Chapter II :	Climatic Peculiarities	23
Chapter III :	Vegetational Characteristics	32
Chapter IV :	Some Characteristic Fauna	39

SECTION III : STUDIES ON THE DISTRIBUTION OF THE SOLITARY PHASE DURING 1931—1938

Chapter I :	Introductory : Locust Survey Methods	45
Chapter II :	Account for Years 1931 & 1932	56
Chapter III :	Account for years 1933 & 1934	77
Chapter IV :	Account for year 1935	104
Chapter V :	Account for year 1936	130
Chapter VI :	Account for year 1937	151
Chapter VII :	Account for years 1938-39	180

SECTION IV : STUDIES—EXPERIMENTAL : ECOLOGICAL : BIOMETRICAL

Chapter I :	Results of Experimental Studies	206
Chapter II :	Results of Ecological Studies	255
Chapter III :	Results of Biometrical Studies	289

SECTION V : GENERAL CONCLUSIONS

Chapter I :	Analysis of Survey Data—1931—38	311
Chapter II :	Seasonal Migration among the Solitaries	328
Chapter III :	Location of Outbreak Centres in North-west India	348
Chapter IV :	On some Contributions of the Scheme to our knowledge of Locusts	351

Page

PART II. STUDIES OF PAST LOCUST INVASIONS IN INDIA

SECTION VI : INTRODUCTORY : METHODS OF STUDY . 357

SECTION VII : INFESTATIONS OF PERIOD—1920 to 1939

Chapter I : Locust Cycle of 1926-1932 : (a) 1926 to 1928 364

Chapter II : Locust Cycle (b) 1929 to 1932 385

Chapter III : Swarmless Interval of 1933 to 1939 . . . 421

Chapter IV : Interval of 1920 to 1925 430

SECTION VIII : INFESTATIONS OF PERIOD—1908 to 1919

Chapter I : Swarmless Interval—1908 to 1911 . . . 439

Chapter II : Locust Cycle—1912 to 1919 . . . . (a) 1912-1915 . . 445

Chapter III : (b) 1916-1919 . . 465

SECTION IX : INFESTATIONS OF PERIOD—1888 to 1907

Chapter I : Locust Cycle—1888 to 1899 (a) 1888 to 1895 . 474

Chapter II : Locust Cycle (b) 1896 to 1899 504

Chapter III : Locust Cycle—1900 to 1907 . . . 521

SECTION X : INFESTATIONS PRIOR TO 1888

Chapter I : Locust Cycle—1861 to 1868 560

Chapter II : Locust Cycle—1869 to 1873 567

Chapter III : Locust Cycle—1876 to 1881 577

Chapter IV : Locust Invasions prior to 1860 594

SECTION XI :—GENERAL CONSIDERATION OF INDIAN INFESTATIONS

Chapter I : Some Inferences 598

Chapter II : Review of Locust Outbreaks during 1861 to 1939 600

Chapter III : Synchroneity of Extra-Indian Infestations with Indian Cycles 609

Chapter IV : Origin, Progress and Decline of Indian Outbreaks 613

Chapter V : Practical Issues 618

SECTION XII : MISCELLANEOUS ISSUES OF THE LOCUST PROBLEM

Chapter I : Other Locusts in India 623

Chapter II : Sun-spot Cycles and Locust Periodicity . . . 631

Local Names of the Desert Locust in Different Linguistic Regions 637

APPENDICES

References to Literature 638

Errata 649

Statements 645

LIST OF PLATES

Facing page

Plate 1.—*High sand dunes in the Mallani area near Bamnor*; dunes covered with grass and scattered of Acacia trees. Various tall bushes in the fore-ground. The granite hill of Chohtan seen at the back of the dunes, November, 1932 17

Plate 2.—*Pugal village on top of a sand dune.*—August 1937. Western Bikaner; an area of undulating sand-dune country; Khejdi trees (*Prosopis*) fairly common around village. Bushes in the fore-ground mostly Murt (*Panicum turgidium*) and Siniya (*Crotalaria burhia*) . . 20

Plate 3.—*Bagar Area of sandy loam soils in Lasbela State.*—A large belt of sandy loams stretches from the banks of the Porali to the sides of the Mor Range in Lasbela State. These soils were evidently formed of blown silt in the course of ages, and forms an vast area which is suitable for egg laying after heavy rainfall. The motor track from Karachi to Sonmiani and Bela passes through a large part of this area. The soil and vegetation are somewhat similar to those of the old dune areas of the Desert . . 21

Plate 4.—Chart showing track of western disturbances 30

Plate 5.—Chart showing track of bay depressions 32

Plate 6.—*Desert to the north of Nokh.*—Mostly covered with large bushes of Lana (*Haloxylon salicornicum*); fairly large clumps of Murt (*Panicum targidum*) were also present—July, 1936 40

Plate 7.—*Open desert area near Girasar (Jaisalmer).*—Ground covered with recent growth (after June rain) of Bekkar (*Indig ofera cordiolia*) in fore-ground, as well as a few grass clumps of Siwan (*Elionurus*). Fairly good numbers of hoppers were seen here in July, 1936 . . 40

Plate 8.—*Grass-covered area of the desert.*—Near Sodakhor (Jaisalmer) November, 1932. Grasses mostly Siwan (*Elionurus*) and Murt (*Panicum*). Several adults of *Schistocerca* and a small number of *Locusta* were found in these areas in November, 1932 . . . 41

Plate 9.—*A rank growth of grass and annuals at Chachro.*—Grass (mostly Bharut.—*Cenchrus catharticus*) and Vishani (*Tephrosia*) and Wekra (*Indigofera cordifolia*) were found rapidly drying up at Chachro in September, 1935 41

Plate 10.—*Sardarshahr Locust Outpost.*—Located on the top of a bare dune. The compound fenced with thorn contains the meteorological plot, as well as a small laboratory and a few huts for the accommodation of the workers 48

Plate 11.—*Chachro Locust Outpost.*—On top of a sand-mound, also showing the desert country roundabout. The larger bushes are mostly Calligonum, Calotropis and Capparis, (February, 1937) . . . 48

Plate 12.—*Desert area between Pugal and Rojri.*—August 1937: Booh plants (*Aerua*) being tapped gently with a stick to note the number of hoppers jumping out of the bushes 49

Plate 13.—*A method of catching solitary locusts.*—A piece of old fishing net is attached to the end of a stick as in photograph. The surveyor keeps as far as possible from the locust and slowly brings the piece of netting nearer and nearer until it hangs vertically over the insect at a distance of about 4 to 6 inches, when it is suddenly dropped flat on the locust. The latter is entangled in the netting and is captured before it can get free 49

Plate 14.—*Pink locust swarms at Quetta.*—Pink locusts were found visiting a lucerne field near Quetta in July, 1931. The field was badly damaged 136

Plate 15.—*Shashtal Rek near Nasirabed in Kech Valley.*—Photograph (taken in February, 1936) of actual site of the Outbreak Centre reported in May—June, 1935. Large bands of incipient swarms of hoppers were said to have been seen here 136

Facing page

Plate 16.—*A patch of cultivation in the desert.—September*, 1936. *Bikaner State* : Mostly Bajri (*Pennisetum typhoideum*), Til (*Sesamum indicum*), and Guar (*Gyamopsis psoralioides*). Hoppers and adults of the desert locust were found in fair numbers here 137

Plate 17.—Rank growths of Chag (*Crotalaria burhia*) and grass (*Panicum* spp.) seen in February 1937 near Nokh, owing to the heavy rains of August 1936. Locusts over-wintered at the base of these bushes in these places 137

Plate 18.—*Camelthorn occurring as a weed in jowari field.*—Nov., 1937 ; Goth Safar Khan near Sheh Lakhra. Hoppers said to feed on camelthorn and other weeds 161

Plate 19.—*Site of breeding at Kirtha in Bolan Valley in June*, 1937.—Large numbers of hoppers of *Locusta migratoria* and *Schistocerca* were found breeding here in cultivation as well as outside 161

Plate 20.—*Breeding cages kept on low benches.*—The legs are fitted with ant-pans to prevent invasion of the cages by ants. Used at Pasni and Ambagh 162

Plate 21.—*Colour Plate*,

Fig. 1.—Young locust with hyaline wings. . . . . .

Fig. 2.—Young locust with hopper markings still visible on pronotum 170

Fig. 3.—Light yellow colour on wings . . . . . .

Fig. 4.—Mature locust with bright yellow wing-colour . .

Plate 22.—*A pair of Solitaria locust observed on the Pasni Rek on 4th February*, 1938. They were difficult to spot. They apparently did not mind the walking stick used for locating them while photographing . 246

Plate 23.—*Colour Plate*,

Fig. 1.—*Gregaria* phase locusts ; wings pinkish . . . . .

Fig. 2.—Young *gregaria* adult ; wings hyaline, body colour pink.

Fig. 3.—Young *solitaria*, body dry-grass colour . . . .

Fig. 4.—Young *solitaria*, body colour greenish, green patches on elytra, pronotum, etc. 246

Plate 24.—*Colour Plate*,

Fig. 1.—*Solitaria adult* : body light bluish ; dorsal stripe, light yellow, wings, pinkish, mauve at base 254

Fig. 2.—*Solitaria adult* ; body brown ; dorsal stripe, dark-brown ; wings deep mauve at base 254

Plate 25.—*A part of Sanzar Rek in the Pasni Rek area.*—Showing the undulating country with high dunes and hollows ; all covered with low scrub vegetation. In the distance are seen the high bare dunes (50 to 120 ft. high) of shifting sand 258

Plate 26.—*Rek Area at Ormara.—February*, 1932 : Vegetation rather dried up for want of rain : composed mostly of Mazoung—(*Sphaerocoma aucheri* and to a less extent Marrand (*Heliotropium undulatum*) and Barshonk (*Panicum turgidum*). Few locusts were seen owing to the dry conditions 258

Plate 27.—*Coastal Reks in the Pohr Hingol area in Lasbela.*—April, 1932. The reks cover a large area along the coast. The river to the left is the Pohr and the hills in the distance the Hara Range, vegetation rather dried for want of rain 259

Plate 28.—*A silt covered with vegetation* on the banks of a watercourse in Kulanch, February, 1936. The hills in the distance are the Talar Range forming the northern boundary of Kulanch. Breeding is known to occur in such reks in years of rainfall 259

Facing page

Plate 29.—*Bagori Rek near Ambagh* : Showing the coastal dunes of shifting sand, partly covered with stunted Tamarisk—1935. Depression in foreground rather moist and covered with grass 262

Plate 30.—*The Meteorological Area at Pasni Field Station.*—Located on top of a low sand dune ; enclosed with barbed-wire fence ; fitted with standard equipment including two screens with thermometers and a thermo-hygrograph, anemometer, wind-vane and sun-shine recorder. A locally made sun-shade is seen at the corner for keeping some of the instruments shaded 262

Plate 31.—*Sun-shine Recorder (Whipple-Casella).*—Mounted on a concrete masonary pillar and kept in the Pasni meteorological compound . 263

Plate 32.—*Wire-gauge Cages 3 ft. by 3 ft. by 3 ft.* with open bottom used for covering plants growing on the ground 310

Plate 33.—Chart showing the general movements of locust swarms in a year of heavy infestation in Northern India 311

Plate 34.—Chart showing the locust situation in the first and the second half of the year in 1934 332

Plate 35.—Chart showing the locust situation in the first and the second half of the year in 1935 333

Plate 36.—Chart showing the locust situation in the first and the second half of the year in 1936 334

Plate 37.—Chart showing the locust situation in the first and the second half of the year in 1937 336

Plate 38.—Chart showing the locust situation in the first and the second half of the year in 1938 346

Plate 39.—*Fine silt on the banks of the river in the Dasht Valley*—Usually cultivated after receipt of floods. Ideal ground for egg-laying by locusts. Outbreak centres were recorded in these areas in 1911 and 1923, ... 368

Plate 40.—*Outbreak centre at Goth Safar Khan near Sheh Lakhra in Lasbela, in February—June,* 1937.—Field found over-grown with Camel-thorn and grasses when examined in November, 1937. Large numbers of hopper, adults were found in this field, in which *Jowari* had been grown, during the spring months . . . 368

Plate 41.—*Desert locust—solitary phase adults.*— Fig 1. Adult locust carrying numerous colonies of bright green algae among the cells of the hindwing. Fig. 2. photograph of cells of the hindwing with colonies of green algae. Fig 3. Adult locust infested with Tyroglyphid mites, colonies of which are to be seen at the base of the hind-wings and abdomen. The white dots are skin moults of mites . 378

Plate 42.—*Fig* 1: The locust situation in 1926.—Spring breeding occurred in Mekran followed by summer flights in June-July in Mekran and Kachhi. Summer breeding in Thar and Mallani and late breeding in Thar, Karachi and Lasbela. Autumn flights were seen in good numbers, in Sind, Baluchistan and Punjab, and in north Gujarat .

Fig. 2 : Shows the places of *solitaria* breeding in the summer of 1933, and the direction of movements of swarms reported to have been seen in the autumn and winter of 1933-1934 . .

Fig. 3 : Shows the direction of movements of the summer flights of the Desert Locust in 1904. There were only few autumn flights, there being very little of summer breeding. The area of activity of the Bombay Locust in the Peninsular area is also shown .

Fig. 4 : Shows the activities of the Desert Locust in 1905, and the areas of summer and late breeding in Rajputana, as well as the extent of the summer and autumn flights. The area of prevalence of the Bombay Locust is also shown 386

Plate 43.—Charts showing the areas of satisfactory rainfall in particular years, wherein breeding could have occurred. Please see the Text-figure 25 for names of the divisions of the Sind-Rajputana desert.

Fig. 1 : 1926 : Good rainfall in July in south and east, followed by heavy rain throughout the desert in August. There was good breeding in August in most of the areas. In September, there was heavy rainfall in the south where late breeding occurred . .

Facing page

Fig. 2 : 1927 : Rainfall was confined in July to Bikaner and the southern parts of the desert ; and in August to the south. No rain in September. Breeding was confined to eastern Bikaner, Marwar and Thar . . . . . .

Fig. 3 : 1935 : Good rainfall all over the desert in July was followed by general *solitaria* breeding, but there was no rain in August but little in September, so that swarms did not develop . . . . . .

Fig. 4 : 1912 : Good rainfall in July in east Bikaner. Thar, south and east Marwar ; further rainfall, which was heavy in south and east Marwar, occurred in August, and gave rise to swarms in these areas 392

Plate 44.—Four charts showing the limits of good rainfall during the years 1928, 1929, 1930 and 1931. In 1930 & 1931, exact information in regard to the location of breeding was obtainable, and it is seen that areas of breeding coincided generally with those of good rainfall .

Fig 1 : 1931 : In July, rainfall and breeding were confined to the eastern parts ; but with the widespread downpour noticed in August, heavy breeding occurred all over Rajputana . .

Fig. 2 : 1930 : In June and July, there was fairly widespread rainfall especially in the eastern parts. In August, rainfall was confined to east Marwar. Breeding was moderate and ceased early in most parts of Rajputana . . . . . .

Fig. 3 : 1928 : Rainfall was comparatively light in July, and somewhat heavier in August, and was confined to Bikaner and east Marwar mostly . . . . . .

Fig. 4 : 1929 : In July, there was heavy rainfall everywhere except in Jaisalmer : in August, heavy rains were received all over Sind and south Rajputana, but there was little rain in Bikaner. Heavy breeding occurred in most parts of the desert . . 402

Plate 45.—*Locust situation in the Indo-Iranian Area in* 1927.

There was widespread spring breeding followed by summer flights which reached as far as Bengal and Orissa in June, summer breeding was moderate ; and the autumn flights were mostly west-bound 414

Plate 46.—*Locust situation in the Indo-Iranian Area in* 1928.

There was widespread spring breeding in Baluchistan ; and the summer flights reached up to Bihar and Central Provinces, summer breeding was limited owing to defective rainfall, autumn flights were few 422

Plate 47.—*Locust situation in the Indo-Iranian Area in* 1929.

Spring breeding was limited to Upper Baluchistan and Upper Persia. Summer flights occurred, and there was, as the result of heavy rainfall, widespread breeding all over North-west India. Autumn flights, were heavy, and reached as far as Bihar, Bombay and Baluchistan 424

Plate 48.—*Locust situation in the Indo-Iranian Area in* 1930.

There was wide-spread spring breeding in Baluchistan, Persia, Punjab and the United Provinces. Summer flights reached up to Bihar and Orissa. There was widespread summer breeding in Punjab, Sind, Rajputana and the United Provinces. Autumn flights reached east as far as Assam, and south as far as Warangal and Kolaba. There were no westward flights 446

Plate 49.—*Correlation of locust at flights with wind movements.* May 1930.

During the latter part of May, movements were west to east in general in Punjab and the United Provinces . . . 454

Plate 50.—*Correlation of wind movements and locust flights.*—July 1930.

In the early part of July, movements were mostly from east to west in the United Provinces and the Punjab 456

Facing page

Plate 51.—*Locust situation in the Indo-Iranian Area in* 1931.
Flights of over-wintered yellow locusts of Oman origin invaded Iran and Baluchistan in March-April and led to moderate spring breeding. Summer flights were limited. Summer breeding occurred in Rajputana, south Punjab and western United Provinces. Autumn flights were mostly directed westwards 465

Plate 52.—*Fig.* 1 : *Locust situation in India in* 1914.
Good spring breeding followed by summer flights and fairly good summer breeding. Autumn flights reached Bihar in October.
Fig. 2 : *Locust situation in India in* 1915.
Heavy spring breeding in Baluchistan followed by summer flights reaching as far east as Assam by July. Very little summer breeding on account of a defective monsoon. Very few autumn flights 478

Plate 53.—*Fig.* 1: *Locust situation in India in* 1906 : The spring generation invaded India from the west by the middle of May, and reached as far as Bihar by June. Fairly heavy summer breeding occurred in Rajputana in July-August, and late breeding was noticed in the Punjab in September. Autumn flights reached as far east as Khasi and Jhaintia Hills in Assam, and penetrated much of Bengal.
Fig. 2 : Locust situation in India in 1907.
There was fairly heavy spring breeding ; and the spring-bred swarms reached as far as Bengal by July. Summer breeding did not develop much on account of heavy rainfall. Autumn flights were comparatively restricted 496

Plate 54.—(After the Climatological Atlas of India).
Shows the distribution of pressure and winds at 4 P.M. in July. Typical monsoon pressure gradients are seen with the lowest pressure area located in north Sind. The winds are south-westerly over the Peninsula, and easterly in the Indo-Gangetic Plain . . 520

Plate 55.—(After the Climatological Atlas of India). . . . .
Shows the *distribution of pressure, humidity and winds at* 4 P.M. in October. The Rajputana area is seen to be a region of low humidity. The winds are westerly on the Indo-Gangetic Plain, and north-easterly in general in the Peninsula 552

Plate 56.—Graph showing a curve of fluctuations of sunspot numbers from 1796 to 1944 with a super-imposed curve of rise and fall of locust infestations in India . . . . . .
Prior to 1861, the locust infestation curve is hypothetical, and connects a few disjointed and isolated data regarding locust occurrence. From 1861 onward the curve is based on reliable information. There would appear to be a kind of inverse correlation between the solar and locust data, though in certain places there are secondary rises in locust infestation as during 1896-98, 1905-07 and 1929-31. The durations of *Patanga* (Bombay Locust) and *Locusta* (migratory locust) infestations are also indicated for comparison 574

Plate 57.—*Locust situation in India in* 1899 : Heavy spring breeding in Punjab and Baluchistan ; followed by extensive summer breeding in Rajputana. Autumn flights reached as far south as Tiruvallur near Madras City, and as far east as Assam 584

Plate 58.—*Locust situation in India* 1891 : There was apparently heavy spring breeding in the western areas ; and the summer flights from the west spread up to Assam and Orissa in the east ; and to the south, up to Cuddappa and Nellore in Madras, by June. Summer breeding was scanty and there were comparatively few autumn flights 588

Plate 59.—*Locust situation in India in* 1878 : Summer flights commenced by end of May and reached by June, as far as Hamirpur in U.P. and the Ganjam coast to the east. Extensive summer breeding occurred in the desert and parts of the Punjab ; and also some late breeding in autumn in Punjab and Kathiawar. Autumn flights reached as far as Hill-Tipperah in the east, and as far south as Dharwar in Bombay and Nellore and Kistana in Madras. There was, in addition, an extensive outbreak of the Migratory Locust (*Locusta migratoria*) in South India in 1877-78 622

LIST OF TEXT FIGURES

No.		Facing page
1	Chart showing loose transverse dunes (From Survey of India Maps) . .	16
2	Graph showing the relationship between soil-temperature and incubation period at Pasni	176
3	Graph showing relationship between air temperature and hopper development at Pasni	177
4	Chart showing the various parts of the Pasni Rek areas	264
5	Graph showing the variations of monthly average of daily mean atmospheric humidity in screen at Pasni for the years 1932 to 1938	265
6	Graph showing variations of monthly averages of daily mean temperature at Pasni for the years 1932 to 1938	272
7	Graph showing variations in mean daily temperature and humidity in screen and sand-surface temperature at Pasni during a series of years . .	273
8	Graph showing variations—do—at Sardarshahr	274
9	Plant Quadrant chart showing disposition of plant components . .	275
10	Bioclimatograph for Pasni	276
11	Bioclimatograph for Ambagh	Text fig. 12
12	Bioclimatograph for Chachro	Text fig. 11
13	Graph showing the fluctuation of meteorological factors and their effect on the migration of locusts at Pasni	277
14	Graph showing the correlation of meteorological data with fluctuations of locust population during September-October at Chachro in 1936 . .	278
15	Graph showing the correlation of daily changes of temperature, humidity and evaporation with fluctuations of locust population at Chachro in September 1936	279
16	Structural differences between phases *solitaria* and *gregaria* : Figs. 1 & 2. Sideview of prothorax ; Figs. 3 & 4 : dorsal view of head and pronotum ; & Figs. 5 & 6 : contour of face ; 'P' -Length of pronotal crest; 'H'-Height of pronotum ; 'M'-Breadth of pronotum at constriction; 'C'-Maximum width at genal area of face ; 'O'-Maximum width at ocular area of face	294
17	Venation of Tegmen of the Desert Locust, Fig.1 showing venation including nervures. Fig. 2, the same without nervures. The following veins are shown: Costa, Sub-costa ; Radial, Radial Sector with branches: Median, anterior and posterior with branches; Cubitus, Post-cubitus, Cubito-median cross-vein ; Anals : 1 & 2 ; 'V'-the apex of the Anal (or Vannal) areas of Tegmen	295
18	Four figures showing eye-stripe types : Fig. 1, with 5 stripes, Fig. 2, with 6 stripes; Fig. 3, with 7 stripes & Fig. 4, with 8 stripes	312
19	Types of Antennae found in forms with different types of eye-stripes . .	313
20	Graph showing the fluctuations in the density of locust population at Pasni and Ambagh in successive year	320

No.		Facing page
21	Graph showing the fluctuations in the density of locust population in successive years at the three Desert Observation Stations	321
22	Graph showing the relationship between the locust populations of the different parts of the Indian area in successive years based on their biometrical facies	365-366
23	Map of southern Baluchistan showing the main reks and the disposition of possible 'outbreak centres'	369
24	Copy of 'India Daily Weather Chart for September 23, 1930', illustrating the development of northerly winds in the regions of Central India, Central Provinces, Hyderabad and Madras under the influence of depression at the head of the Bay of Bengal	376
25	Skeleton map indicating the names of the divisions of the Sind-Rajputana area included in Plates No. 43 and No. 44	377

LIST OF STATEMENTS

	Page
Statement I—Tabulated Results of Locust Surveys, 1931	63
Statement II—Tabulated Results of Locust Surveys, 1932	75
Statement III—Tabulated Results of Locust Surveys, 1933	89
Statement IV—Tabulated Results of Locust Surveys, 1934	101
Statement V—Tabulated Results of Locust Surveys, 1935	128
Statement VI—Tabulated Results of Locust Surveys, 1936	149
Statement VII—Tabulated Results of Locust Surveys, 1937	179
Statement VIII—Tabulated Results of Locust Surveys, 1938	202
Statement IX—Monthly Meteorological Data for the period Dec. 1937 to Nov. 1938—*Pasni*	650
Statement X—Monthly Meteorological Data for the period Dec. 1937 to Nov. 1938—*Ambagh*	654
Statement XI—Monthly Meteorological Data for the period Dec. 1937 to November 1938—*Nokh*	656
Statement XII—Monthly Meteorological Data for the period Dec. 1937 to November 1938—*Chachro*	660
Statement XIII—Monthly Meteorological Data for the period Dec. 1937 to November 1938—*Sardarshahr*	664
Statement A—Analysis of generation experiments	668
Statement B—Incubation Period in relation to Soil Temperature, etc.	672
Statement C—Influence of quality of food on sex-maturity (I & II)	676
Statement D—Amount of dried faecal matter of female in respect of different food-plants	217
Statement E—Duration of hopper period as affected by different food-plants	695
Statement F—Amount of dry faecal matter per hopper per day for different food-plants	221
Statement G—Food preference values of the more common plants at Pasni	231
Statement H-i—Correlation of eye-stripes and larval instars—Karachi	700
Statement H-ii—Results of rearing hoppers on different food-plants in regard to eye-stripes	706
Statement J-i—Effect of sunlight on the colour of wings—Experiments at Pasni, Karachi, etc.	710
Statement J-ii—Effect of sunlight on the colour of wings—Experiments at Ambagh, 1937	719
Statement Ec. I—Some of the common flora of the Pasni Reks	281
Statement Ec. II—Some of the fauna of the Pasni Reks	284
Statement B.R. I—Relationship of E/F to other ratios	291
Statement B.R. II—Comparative examination of *Solitaria* and *Gregaria*	294
Statement B.R. III—Relationship between E/F & V/F ratios	297
Statement B.R. IV—Relationship between E/F & C/O ratios	301
Statement B.R. V—Analysis of antennal types in relation to eye-stripes & E/F ratios	305
Statement XIV—Results of liberation of marked locusts	338

PART I

STUDIES ON THE LIFE HISTORY AND ACTIVITIES OF THE SOLITARY PHASE OF THE DESERT LOCUST (*SCHISTOCERCA GREGARIA* FORSKAL) IN ITS NATURAL BREEDING GROUNDS IN INDIA DURING THE PERIOD 1931 TO 1938

SECTION I—INTRODUCTORY

CHAPTER I

GENESIS OF LOCUST INVESTIGATIONS IN INDIA

THE earliest known record of locust invasions is probably the one graphically described in the tenth chapter of the Exodus in the Old Testament, *circa* 1491 B.C. [Bodkin, 1929]. So far as known, there is no definite historical record of past locust infestations in ancient India, but mention is made in Sanskrit literature of the third or fourth century of the Christian era, of 'locust menace' as one of the six recognized hazards of the cultivators, from which it follows that locust outbreaks were, presumably, of fairly frequent occurrence in those early days also.

Periodicity of locust invasions

Although, reports of locust invasions in India during the seventeenth and eighteenth centuries, often associated with famines, have been handed down by tradition, it is only from the year 1803 (*Bombay Gazetteer*, 1880), that authentic records of their occurrence may be said to commence. According to Cotes [1891], serious outbreaks occurred in the following years: 1812, 1821, 1843-44, 1863, 1869, 1878 and 1889-92, and since 1892, heavy infestations have been recorded during the years: 1896-97, 1901-03, 1906-07, 1913-15 and 1926-30. These data would indicate the existence of a certain degree of periodicity in respect of their recurrence and unless evidence to the contrary is forthcoming, there is no reason to consider that locust incidence in India had not been governed by a similar periodicity in times prior to this recorded period.

From the available records, it is obvious that infestations of the desert locust have been appearing in northern India in fairly distinct cycles. In general, outbreaks would appear to last four to eight years, after which swarms disappear for a longer or shorter period, during which few locusts are noticeable. Sooner or later, locust swarms reappear, often very suddenly and usually in enormous numbers. Their onslaughts are sometimes so unexpected that neither the people nor the administration are prepared to meet them, with the result that extensive damage is caused to cultivation over a wide area.

The infestation of 1927—1929

Since 1913-15, few locust swarms had been seen anywhere in India, and, in fact, according to Richards [1931], no breeding had occurred in the United Provinces until 1927 for over 50 years. In September 1926, locusts appeared in Sind and Rajputana rather suddenly [Mann and Burns, 1927] and breeding occurred. By October, November and December, swarms entered Gujarat, the Punjab and Baluchistan and caused damage to crops. In the spring of 1927, serious infestation was reported from the Punjab, Baluchistan and parts of the United Provinces. Summer breeding also occurred in the Punjab. During 1928, the infestation was not very serious except in parts of Baluchistan. In the summer of 1929, however, very serious and widespread infestation was reported all over the plains of northern India, especially in Sind, the Punjab, Rajputana and the United Provinces, and the extensive damage done by hopper and adult swarms caused general consternation among the agricultural population all over the country.

The widespread depredations of locusts naturally received prominent notice in the Indian press. Almost every day, reports of fresh attacks in new areas featured in the telegraphic columns, and served to focus the interest of the public, as well as of the Government, on the seriousness of the locust problem. In the United Provinces and the Punjab, as well as in Sind, Baluchistan and the North West Frontier Province, fighting the locust menace formed, while the infestation lasted, one of the major activities of their respective Revenue Departments. The Punjab and the United Provinces had the advantage of the expert advice and help of their entomologists, and the campaign instituted under their guidance and carried out by an efficient and extensive locust control organization resulted in greatly minimizing the damage to crops. Usually, in the province of Sind, locust breeding is restricted to the desert areas of the Tharparkar district and the rest of the province suffers mostly from the depredations of passing locust swarms, but in 1929, as a result of heavy and widespread rainfall, locusts laid eggs all over the province and brought about an abnormally high infestation, which threw a heavy strain on the energies of the Revenue and Agricultural Departments in their attempts to control them. In Baluchistan, heavy summer breeding occurred in the eastern districts in addition to spring breeding, resulting in much damage to crops and grass. In the various States of Rajputana also, fairly severe infestation had evidently occurred during the monsoon rains, though little official information is on record.

The general situation in regard to the locust outbreak was thus, on the whole, very gloomy during the autumn months of 1929, and it was evident that, in view of the magnitude of the trouble, some urgent measures were required.

Need of a centralized organisation for control and intelligence

Locust swarms have enormous powers of migration, so that breeding taking place in a corner of the country may subsequently affect another distantly situated area. Control measures designed to protect solely certain particular fields under cultivation, without reference to the surrounding infestation in waste land, will obviously be of little or no practical value in fighting the locust pest. For practical locust control a coordinated organization is needed which can deal with all areas, whether cultivated or not, in which locust breeding is observed.

Moreover, although a system of getting prompt reports of locust appearance from the village officers was in practice in the Revenue Departments of some of the provinces, and, in certain cases, advice in regard to the movements of swarms was being given to the adjoining areas, there was no system of centralized intelligence on this matter for the whole of India. Whereas recent studies of locust movements have made it clear that the great swarms that appeared rather unexpectedly in July 1929 in the Punjab and the United Provinces originated from Baluchistan and Iran, there was no arrangement at that time for conveying information about heavy breeding in Baluchistan or Iran to provinces liable to locust invasion in India.

Lack of information on the origin of the infestation

In respect of information as to the origin of the locust swarms that visit India, the Locust Committee of the Board of Agriculture that met at Pusa in December 1929 made the following statement: 'There is reason to believe that the locust invasions that cause periodic losses in India have their origin not only outside India, but in remote countries. North India appears to be the eastern limit of the area affected by the Desert Locust, which extends to North Africa on the west' (*Pr. Bd. of Agr.*, 1929). In fact, beyond a general impression that swarms usually entered India from a

western source, perhaps from Iran, Arabia or Africa, and in general, travelled in an eastern direction, there was no definite information in regard to the origin of the swarms, the general routes followed by locust flights or the factors concerned in the migration of swarms. Cotes [1891] was of opinion that the desert region of western Rajputana contained some of the permanent breeding areas of the locust, besides which he also considered that the country to the west of the Suleiman Range, *viz.* the region bordering on Afghanistan and Baluchistan, contained some breeding grounds. The question as to whether any permanent breeding grounds of the locust existed within Indian territorial limits assumed additional importance since the enunciation of the 'Phase Theory' of Uvarov in regard to the origination of migratory swarms.

Infestation outside Indian limits

In the meantime, it became evident that the trouble from locust incursions was by no means restricted to India. Outbreaks of the Desert Locust were reported almost simultaneously from Persia, Arabia, Syria, Palestine and Iraq and also from Egypt and other parts of North Africa. Apparently, the locust developments in India were part of a much wider movement spread over the entire area of the habitat of the Desert Locust. The dangers of the locust menace in Africa were indeed so great as to engage the urgent attention of the British and French authorities in respect of a study of the pest in their respective territories. The British Committee of Civil Research immediately formed a Locust Sub-committee (subsequently transformed into the Committee of Locust Control of the Economic Advisory Council) to consider the locust problem in all its aspects and to report on the steps to be taken towards (i) the control of the pest, (ii) the location of possible permanent breeding areas and migration routes and (iii) the investigation of the bionomics of the locust and the periodicity of its outbreaks. This resulted in the formation of an extensive scheme of locust research under the supervision of the Imperial Institute of Entomology, London, covering the entire area subject to locust attack in Africa, as well as in western Asia. Also, various missions of Anti-Locust Research were organized in the French possessions in Africa with similar objects.

Resolutions of the Board of Agriculture in India

In the circumstances detailed above, the locust problem in India received considerable attention both from the Imperial Council of Agricultural Research at a meeting of the Advisory Board early in December 1929, and the Board of Agriculture in India at its 15th meeting held at Pusa in the middle of December 1929.

The Board of Agriculture passed resolutions recommending (i) the immediate formation of a Central Intelligence Bureau for summarizing and disseminating all information regarding locust attacks and movements and warning areas liable to attack of any impending invasions, (ii) the securing of the necessary staff at once for carrying out (a) an investigation on control measures, (b) a survey of permanent breeding grounds of the Desert Locust in India, and subsequently (c) further researches on the bionomics of the locust, (iii) the immediate provision of adequate funds, apparatus and labour for the complete eradication of the pest, and the adequate organization of staff and material for locust control in each province or State liable to locust invasions, and (iv) the storing of an adequate stock of material for anti-locust campaigns by the Central Government for issue to provinces or States as required.

Appointment of a Standing Locust Committee

The Advisory Board of the Research Council recommended the formation of a Standing Committee to consider the steps to be taken for meeting the serious locust situation and for dealing with all matters relating to

locusts. The proposal was promptly sanctioned by the Governing Body by the end of December 1929. The newly constituted Locust Committee of the Research Council was composed of the Vice Chairman and the Agricultural Expert of the Imperial Council of Agricultural Research, the Directors of Agriculture and the Entomologists of the provinces and States affected, and certain administrative officers connected with locust control. The body met on 17, 18, and 19 February 1930 and made recommendations for the formation of a Central Locust Bureau, fully endorsing the findings of the Board of Agriculture regarding the need for collection and dissemination of locust intelligence. In an interim report, the Committee also considered the control measures that might be deemed suitable for general adoption in areas affected by locusts. The methods of control recommended by the Committee were subsequently issued in a pamphlet form and copies were supplied to all provinces and States concerned.

The Locust Committee met again in May at Simla on the 15th, 16th and the 17th, and after reviewing the action taken on the recommendations of the interim report, went fully into the question of arranging for a scientific study of the Desert Locust in India. They were unanimous about the necessity of research in India both in regard to methods of control, and in regard to studies of the annual cycle and periodicity of the locust in the Indian area. After mature deliberation, the Committee came to the conclusion that locust research in India should be divided into two distinct sections, one dealing with the highly cultivated alluvial plains of north-western India, composed of the Punjab, the North-West Frontier Province, the United Provinces, etc. and the other with the more southern regions predominently of a desert character comprising Baluchistan and parts of Sind and Rajputana. The first group included areas in which the locust bred only when it appeared in swarms, whereas the second evidently contained areas in which the locust was possibly endemic and in which locust swarms generally appeared earlier than in the plains' group. Moreover, while the problem of control might be anticipated to loom large in the alluvial plains, the main work in the desert areas would be concerned with the search for locust breeding grounds and a study of the insect in its natural habitat. It was, therefore, recommended that the research problems should be divided between two separate units: one, with headquarters at Lyallpur, attending to research on control and bionomics, and the other, with Quetta as centre, mainly concerned with survey work in the desert area.

Sanction of a Locust Research Scheme

After full consideration, however, the Governing Body of the Research Council sanctioned a unified scheme of Locust Research at a total expenditure not exceeding Rs. 1,76,000 under a Locust Research Entomologist, Khan Bahadur M. Afzal Husain with headquarters at Lyallpur. He was to be directly responsible for research work on the bionomics and control of the locust, for which a fairly adequate staff was provided, and the survey work in the desert areas was to be looked after by a Deputy Locust Research Entomologist under his control, stationed at Quetta. The staff was selected by the end of 1930 and began to function from January 1931. The ultimate outcome of the various deliberations made by the Imperial Council of Agricultural Research on the subject of the locust menace in India, therefore, was (i) the formation of a Standing Locust Committee to advise the Council on locust matters, (ii) the institution of a Central Locust Bureau for the broadcasting of locust intelligence, and (iii) the initiation of an intensive scheme of locust research in India, including investigations on the bionomics of the locust, its control, its breeding grounds and its field ecology. It is proposed now to review in brief the progress made under these heads since 1930 up to March 31. 19

CHAPTER II

REVIEW OF THE PROGRESS MADE BY THE LOCUST ORGANIZATIONS

The Standing Locust Committee

THE Committee first met in February 1930 to advise on matters of control methods, and again in May 1930 to consider schemes of locust research. It next met at New Delhi in January 1932, to examine the results of the investigations in progress at Lyallpur and in Baluchistan under the new scheme of the Locust Research and made, after due consideration, various suggestions in regard to the continuation of the work. Thereafter, it met annually, during the period 1933 to 1939, for reviewing the periodical reports of the research staff and making suitable recommendations from time to time, on proposals for further work.

With the establishment of a Locust Warning Organization by the Government of India in 1939 to watch locust developments in the desert areas, the Locust Committee was abolished in 1940.

The Central Locust Bureau

In May 1930 a Central Locust Bureau was brought into existence according to the recommendations of the Board of Agriculture and the Locust Committee. Reports of locust activity received from various parts of India were collected and studied. Summaries of these reports were prepared and broadcasted to all the authorities concerned with locust control. Periodical communiques giving warnings about impending locust incursions or outbreaks were also issued. From May 1930 to April 1931, an Entomologist (Rai Bahadur G. R. Dutt, B.A.) was attached to the Locust Bureau and was largely employed in rendering assistance to Indian States in the demonstration of anti-locust measures, as well as in the organization of an intelligence service. He also attended to the study of the locust movements reported in 1930 by mapping them out fortnight by fortnight.

The reports received and broadcasted by the Locust Bureau during 1930 and 1931 form a fairly full and complete record of the locust movements in the Indian region and afforded valuable data for the study of locust activities in correlation with meteorological records.

Owing to the disappearance of swarms the work of the Locust Bureau was restricted, since 1932, to the circulation of mostly *nil* reports of swarm activity, except for a few flights reported in 1932, 1933 and 1935, though later on brief information on the activities of the solitary phase locusts, studied by the Locust Research Entomologist, Karachi was also included therein. The Locust Bureau was also obtaining reports about locusts from parts of Arabia and Iran through appropriate official channels, and also of locust movements in other parts of the world from the International Anti-Locust Centre in London, and communicating the information to members of the Locust Committee and to administrations interested in locust control. It may be added that, from the outset, copies of the reports issued by the Locust Bureau were being regularly supplied to the Imperial Institute of Entomology, London, to be used in the compilation of their annual surveys of the locust outbreak in Africa and western Asia. Since November 1939, the duties of the Locust Bureau were taken over by the Director, Imperial Agricultural Research Institute, New Delhi.

The Locust Research Scheme

As sanctioned by the Governing Body of the Imperial Council of Agricultural Research, a unified scheme of locust research came into existence at the close of 1930 under the charge of Khan Bahadur M. Afzal Husain, M.A. (Cantab), M.Sc., Punjab Government Entomologist, appointed as Locust Research Entomologist to the Imperial Council of Agricultural Research with headquarters at the Punjab Agricultural College, Lyallpur. As decided at a meeting of the Locust Committee, the scheme was divided into two distinct sections: one, dealing with a detailed study of the bionomics of the Desert-Locust, as well as with a critical study of the economics of different methods of locust control; and the other, related mainly with the investigation of the permanent breeding grounds of the locust, in the desert areas of Baluchistan, Sind and Rajputana.

The first section of the scheme was located at the laboratories of the Government Entomologist, Lyallpur, and was directly under the charge of the Locust Research Entomologist aided by a staff of two Assistant Entomologists and five research assistants and nine fieldmen, and the other was placed, subject to his control, under a Deputy Locust Research Entomologist (the writer), with headquarters at Quetta, with a staff consisting of an Assistant Locust Research Entomologist (Dr M. Sharif), three research assistants and six fieldmen.

Research work at Lyallpur

This unified scheme of research was in progress from January 1931 to March 1933. During this period, intensive studies of the life history of the locust were made at Lyallpur. Experiments in regard to a study of the influence of factors such as temperature and humidity on the life processes of the locust, such as the incubation of eggs, the larval life, sex maturation, adult longevity and colour development in hoppers, were in progress. Very interesting data in regard to the effects of crowding, prolonged physical exertion and an excess in the carbon dioxide content of the atmosphere, on the coloration of hoppers were obtained. In addition, various publications on locusts in Russian, German and French were translated with the help of an official translator, Mrs. Makeef. During 1932, there was a reduction of staff at Lyallpur, only three research assistants and six fieldmen being retained.

As the services of Khan Bahadur Afzal Husain were required by the Punjab Government from 1 April 1933 as Principal and Entomologist at the Agricultural College, Lyallpur, the part of the scheme relating to bionomics was separated from the rest and placed directly under the Punjab Entomologist, the funds needed being provided from a special research grant. This part of the scheme continued up to 31 March 1939. Owing to the disappearance of swarms since 1932, however, much difficulty was felt in obtaining live material for continuing the experiments, and in spite of periodical supplies of solitary phase locusts arranged by the survey staff under the Karachi scheme, it was found impracticable to carry on the experimental work as programmed and attention was largely devoted, therefore, to the preparation of the results obtained for publication. Some of these results have been published as a series of articles under the title 'Studies on *Schistocerca gregaria*' with the joint authorship of Khan Bahadur M. Afzal Husain and his colleagues [1933-1940].

Control experiments

In 1931, reports of swarms were received during April and May from Chagai, Kharan and Quetta Pishin areas, and Dr. V. P. Varde and

Mr. Keshodas Baweja were sent there from Lyallpur to carry out control experiments early in May. In the Nushki area, the relative effect of different proportions of sodium fluosilicate used as an ingredient in bran baits on hoppers was tested.

Ring trenching was organized over an extensive stretch (three miles in length) of egg infested area on the beds of two large water courses, the Lora Zafran and the Lora Hyderzai, near Kuchlak in Quetta tehsil, and the operation proved a complete success, serving thereby as a demonstration of the high efficiency of this method to the Baluchistan authorities. Further experiments on locust control were not possible on account of the disappearance of swarms by the end of 1931.

Locust surveys and ecological investigations. (i) *Preliminary surveys, 1931-33.*—During 1931, preliminary field surveys were carried out in various parts of Baluchistan including the Mekran coast. During 1932, an one-and-a-half ton Ford van was provided for purposes of touring in the interior of the semi-desert areas of Baluchistan, Sind and Rajputana, as ordinary facilities of travelling were found lacking in these regions. The survey staff was divided into two parties, who used it alternately for survey work. The following areas were surveyed between January 1932 and March 1933: Karachi, the Sind Valley, Lasbela, Jhalawan, Mekran, Loralai, Dera Ghazi Khan, Bahawalpur, Bikaner, Jodhpur, Sirohi, Palanpur and Radhanpur. In addition, the Tharparkar district of Sind, and the Mallani and Jaisalmer areas of Rajputana were visited by the writer using camel transport exclusively.

(ii) *Ecological work.* As the discovery of green hoppers of the Desert Locust on the sandy *rek* areas near Pasni, Ormara and Gwadar in May 1931, indicated that some of the breeding grounds of the solitary phase were situated on the Mekran coast, the immediate establishment of a field research station for studying its ecology under natural conditions at Pasni was sanctioned. Consequently, the Pasni Field Research Station began to function in January 1932. In addition, one outpost was established at Sonmiani in the Lasbela area. The main object of the station being a study of the influence of the environment on the locust in its natural breeding grounds, records of continuous meteorological observations were maintained at Pasni; and periodical field surveys were also carried out in the surrounding *reks* to note the reaction of the locust to the seasonal changes in the environment. Whereas the western parts of the Mekran coast, as typified by the Pasni station, fall within the zone of regions of winter rains and summer drought, the eastern parts of the Mekran coast come under the influence of the south-west monsoon and are thus predominantly areas of summer rainfall. As the conditions prevalent here were found to be very different from those at Pasni, a small observation station was opened in 1933 at Ambagh on the Lasbela coast, to study the ecology of the locust in an area of summer rainfall. As the solitary type of the locust was also found common in certain parts of the year in the desert areas of Sind and Rajputana two desert outposts were established in 1934, one at Chachro in the Thar area of Sind and a second at Sardarshahr in East Bikaner, and subsequently, a third at Nokh in East Jaisalmer in 1935, for recording the dominant ecological conditions affecting the locust in the desert regions.

On the whole, a large amount of detailed information about the ecology of the Desert Locust under the varied conditions met with at these stations has been accumulated. In addition to ecological observations, a certain amount of experimental work was also carried out, as recommended by the Locust Committee, at Pasni and Ambagh during the years 1935 to 1937, in connection with general problems of the life history of the locust, such as the effect of the various desert food plants on the

sex maturation of the adults and on the duration of the hopper period, the number of generations possible during a year under optimum semi natural conditions in the desert, and the like.

(iii) *Intensive locust surveys, 1933-38.* As a result of the extensive surveys carried out in 1931 and 1932, it was clear that the locust was most in evidence in the desert areas, where it was being met with in the solitary phase form, though it had disappeared from the rest of the country with the dying down of swarm invasions. Since 1933, survey work was, therefore, restricted to such areas, but with the object of studying the reactions of the solitary locust to seasonal changes in the environment, surveys were regularly repeated at different parts of the year.

With the establishment of locust outposts at Chachro and Sardarshahr in 1934, and later on at Nokh in 1935, regular intensive surveys up to a radius of 5 to 10 miles around each outpost were arranged. Similarly, outposts in charge of fieldmen were opened at Gwadar, Turbat and Panjgur in Mekran and at Sukkur as a centre for Kachhi and upper Sind, for keeping a watch over the areas round about. A system of surveys, combining intensive observations at particular centres with periodical extensive scouting tours up to a radius of about 100 miles round about, was thus in practice during the last five years of the scheme, and has contributed evidence of extreme value in regard to the occurrence of migration among the solitary phase locust.

(iv) *Study of old records.* In the course of visits to various parts of Sind, Baluchistan, Rajputana, Southern Punjab and Western India States, the locust survey staff collected all available information in regard to locust infestations in past years. In addition, season and crop reports published in the *Gazettes* of various provinces subject to invasion, such as the Punjab, Bombay and Sind, were studied, as also the periodical *Diaries* of the political officers of the Baluchistan Administration. Information was also collected from the annual administration reports of the various States of Rajputana and from the Gazetteers of various provinces and States.

The data thus gathered were arranged chronologically, and the locust movements indicated therein were mapped out month by month for the period 1869 to 1931 for the whole of north-west India (with the exception of the data for the period 1926-1931 for the Punjab, the North West Frontier Province and the United Provinces, which were studied by Khan Bahadur M. Afzal Husain and his staff at Lyallpur). A limited number of copies of the chronologically arranged locust data, covering the period from 1803 to 1931, were printed for permanent record and reference and for supply to interested entomologists.

(v) *Biometrical work.* In the course of locust surveys, it was observed that specimens of solitary phase locusts collected in different places exhibited much variation in body coloration, the colour of the wings and the general development of the body. In order to find if these differences were associated with a change of phase, the writer took with him to London at the time of his deputation to the Third International Locust Conference held in September 1934, a large collection of locusts found in the desert areas between 1931 and 1934. After the close of the Conference, a biometrical examination of the collection was made by him at the Imperial Institute of Entomology with the kind help and guidance of Dr B. P. Uvarov. After his return to Karachi in November 1934, the

biometrical work was continued by him as time permitted. While at the beginning, biometrical examination of locusts was more or less restricted to the determination of the ratios based on measurements of different parts of the body of the insect, other characters such as wing colour and the number of eye stripes and antennal segments were also taken into consideration later on. These biometrical studies have been of much service in determining the affinities of particular groups of locusts collected at particular seasons or localities, in deciding if any particular individual was a locally bred form or a migrant, and in detecting tendencies towards a change of phase.

International Locust Conferences. With the spread of the locust outbreaks in different parts of Africa and western Asia and the institution of various research schemes in the affected countries, it was soon felt that it would be of mutual advantage to arrange for a contact between the workers in the different countries not only in regard to the supply of reliable information on the movements of swarms but also in regard to a mutual exchange of their experiences on various aspects of locust research and control. As an international conference on anti-locust matters was obviously the best way to bring about this end, the first conference was held at Rome in October 1931 under the auspices of the Italian Government. It was followed in July 1932 by the Second Conference held at Paris at the invitation of the French Government. The Third International Conference was convened by the British Government in September 1934 in which India was represented by the writer. The Fourth Conference met at Cairo in April 1936 at the invitation of the Egyptian Government in which Khan Bahadur M. Afzal Husain participated as a delegate from India. The Fifth Conference was held under the auspices of the Belgian Government at Brussels in August 1938. Though India was not represented by a delegate at Brussels, three papers on locust work in India were submitted for the conference. The Fourth and the Fifth Conferences included delegates from over 20 countries, including various States of the New World also.

In the course of the deliberations of these conferences, various aspects of locust research were thoroughly discussed. The knowledge and experience gathered under the different schemes were pooled and the results of the deliberations were embodied in a series of resolutions, which were circulated to the various governments subject to locust infestations for information and for such action as might be considered possible. In addition to the formal discussions, the conferences provided opportunities for workers from different countries to get into intimate and informal contact with one another, and there is ample evidence to show that the progress of the Indian investigations was greatly benefited by the discussions, formal as well as informal, that took place on various aspects of the locust problem. It is also a matter for satisfaction that India was not without its own peculiar contributions to make towards the general pool of knowledge at these conferences.

The British and French Research Schemes. As already mentioned, the locust infestation that started in 1926 was by no means limited to the Indian area. It proved to be part of a widespread outbreak that had come into being almost simultaneously over a vast region extending from the Atlantic shores of western Africa, across the Red Sea and the Persian Gulf, right up to the eastern boundaries of Assam. As vast areas in French and British African Territories were thus affected, requisite action was taken by their respective governments not only to organize control work and arrange for an immediate circulation of reports

of locust movements, but also to carry out investigations in respect of the origin of the locust infestations.

As far as the British areas were concerned, the Imperial Institute of Entomology, London was in charge of the organization of the investigations of various locust problems. In the course of the last ten years, a large amount of work was accomplished, of which a brief mention may be made, at least of some of the major items. Surveys of vast areas of Africa and Arabia were undertaken with the aim of discovering the outbreak centres of the Desert Locust, and subsequently of two other locusts of Africa, the Tropical Migratory. Locust (*Locusta m, migratorioides* R. & F.) and the Red Locust (*Nomadacris septemfasciata* Serv.). Maxwell-Darling's visits to the various parts of Sudan, the Red Sea Coast, and the coastal areas of Aden, Hadramaut and Oman territories of Arabia have added a great deal of information on the outbreak areas of the locust, and Kennedy's valuable work on the behaviour of the locust in the outbreak centre at Hamashiameb on the Red Sea coast of Sudan is an outstanding contribution to our knowledge of locust epidemiology.

In the laboratory, Hamilton's work on the effect of various environmental factors such as temperature and humidity on hoppers and adults of the three major locust pests has contributed much to our knowledge of locusts. The very interesting experiments on the use of poison dusts on flying swarms from aeroplanes conducted by King and others in Rhodesia and South Africa indicate the need of more extensive trials before its general adoption can be recommended [King, 1934].

As per resolutions passed at the First International Locust Conference held at Rome in October 1931, the Imperial Institute of Entomology, London, became the international centre for locust information and all locust intelligence received from all the affected areas was promptly mapped and studied. The first comprehensive survey of the movements of swarms in Africa and western Asia, during the period 1925—1931 [Uvarov, 1933] was of extreme value in presenting a clear analysis of a confused mass of data that had accumulated during those years of heavy infestation. This was followed by equally valuable yearly surveys [Uvarov, 1934, 1935, 1936; Uvarov and Milnthorpe, 1937, 1939] in which a full account of the movements of swarms of all the three important locusts of Africa and western Asia has been given year by year for the years 1932 to 1937.

The French organization under the *'Comite d'Etudes de la Biologie des Acridiens'* have contributed a great deal to a knowledge of the distribution of the desert locust in the regions of western Mauretania, the Spanish territory of Rio de Oro, Spanish and French Sahara, French West Africa and French Sudan. Their investigations have thrown much light on the physical and vegetational features of these areas and have also brought some evidence on the existence of solitaria migration in these regions.

The results of the joint investigations of French and British workers on the origin of the recent great infestation of the Tropical Migratory Locust covering the greater part of the African Continent have conclusively shown that it had originated in a comparatively small area in the region of the Niger Bend in French Sudan in 1926-27, and had gradually spread wider and wider until the outbreak extended over an area of about ten million square miles. This is a discovery of great importance, since it shows that the infestation could have been nipped in the bud if the original outbreak centre had been controlled at the proper time. Similarly, the collaboration of British, French and Belgian scientists has served to delimit the outbreak centres of the Red Locust in Central Africa.

CHAPTER III

COST OF THE SCHEME

Cost of the entire Scheme in India

At the time when the Locust Research Scheme was originally put up, it was not anticipated that the scheme would take more than two years for completion and the sanctioned estimate of the cost of the scheme was under rupees two lakhs. As work progressed, however, it became obvious, that, if results of value were to be expected, the very nature of the work would necessitate its continuation over a series of years. It may be stated that at the beginning of the investigation, the issues in question were by no means clear. It was only as the work developed, and researches instituted in India and simultaneously in other parts of the world began to throw light on the intricacies of the locust problem, that a satisfactory interpretation of the observed data became possible. In fact, it was not until the great incursion of locusts noted in 1935 occurred that an appreciable advance of a knowledge of locust developments was made in India. Although at the time of writing, our knowledge of locust epidemiology is inconceivably greater than at the commencement of the work in 1931 it cannot, by any means, be contended that we have reached the final solution of the problem. As further experience is gained the provisional conclusions outlined in the present report will have to be modified wherever necessary.

The total expenditure incurred by the Imperial Council of Agricultural Research in connection with locust control and research work from December 1930 to 31 March 1939 amounts approximately to Rs. 7,58,522. which may roughly be apportioned under the following heads:

	Rs.	As.	P.
1. Expenditure on Locust Committee; 1930-39	3,984	2	0
2. Expenditure on Central Locust Bureau; 1930-39...	40,504	9	3
3. Purchase of sodium fluosilicate; 1939	1,756	12	0
TOTAL	46,245	7	3
4. Cost of Locust Research Scheme:			
(a) Lyallpur Bionomics Work:			
Expenditure in 1930-33	1,11,084	7	0
Grant for Punjab Scheme 1933-39	35,195	0	0
TOTAL	1,46,279	7	0
(b) Desert Survey Work, Quetta-Karachi:			
Approximate total expenditure; 1931-39 ...	5,65,997	3	2
GRAND TOTAL for entire scheme...	7,58,522	1	5

It is seen from the above figures that excluding expenses incurred on the Locust Committee, the Central Locust Bureau, and the purchase of sodium fluosilicate, amounting in all to about half a lakh of rupees, and on the Lyallpur Bionomics Work [1931-1939] amounting approximately to Rs. 1½ lakhs, the cost of the locust survey scheme during a period of over eight years was about 5½ lakhs.

Personnel of the Locust Research Scheme

With the exception of the Locust Research Entomologist and the Deputy Locust Research Entomologist, who were selected for duty under the Imperial Council from the provinces of the Punjab and Madras respectively, most of the superior technical staff were recruited through the Federal Public Service Commission. In 1932, survey work was

reorganized and a motor lorry was provided for the staff for carrying out extensive surveys in Sind, Rajputana and Baluchistan, and a field research station was opened in January 1932 at Pasni on the Mekran coast under an Assistant Locust Research Entomologist for carrying out a thorough study of the ecology of the solitary phase of the Desert Locust in one of its permanent breeding grounds. The work on bionomics was continued at Lyallpur with a slightly reduced staff.

In 1933, the work on locust bionomics was taken over by the Punjab Government Entomologist with the help of a research grant from the Imperial Council of Agricultural Research, while the rest of the scheme of locust research was placed under the writer with headquarters at Karachi. Extensive tours were replaced by a system of intensive regional surveys, the staff being suitably distributed in the desert areas of Sind, Rajputana and Baluchistan. In addition, another field station for ecological observations was opened at Ambagh in the Lasbela coastal area. In 1934 and 1935 some desert outposts were established in typical areas of the Sind-Rajputana desert, and later three outposts in Mekran at Gwadar, Turbat and Panjgur and one at Sukkur in Upper Sind for making intensive observations on the movements and breeding of locusts were added.

In 1939, the scheme was closed and part of the staff was absorbed in the new Locust Warning Organization of the Government of India on 1 April 1939.

Duration of the Scheme

When the scheme was originally sanctioned, it was considered possible that the greater part of the work programmed could be completed within two years, by the employment of a sufficiently large staff. It was, however, found at the end of the first year that the very nature of the work precluded the possibility of quick results, and after fully going into the report, the Locust Committee that met in January 1932, recommended the continuation of the work in progress for another year with certain modifications. In subsequent years too (1933—1938), the Locust Committee, which met annually, usually in January, for discussing the year's results, made considered recommendations for the extension of the scheme as well as suggestions in regard to requisite changes in the programme of work, until finally, the scheme was closed down in March 1939.

SECTION II—GENERAL FEATURES OF THE INDO-IRANIAN REGION OF LOCUST HABITAT

CHAPTER I

GENERAL PHYSIOGRAPHICAL FEATURES

STUDIES of the distribution of swarms of the Desert Locust during the last cycle of mass-multiplication in Africa and western Asia by Uvarov [Uvarov, 1933-34, 1933-36, 1934 and 1935, Uvarov and Milnthorpe, 1937-41, 1937-42, and 1939] have shown that the spread of the locust may extend, during such periods of invasion, right from Senegambia, Rio-de-Oro, and Morocco on the Atlantic coast of Africa to Assam in north-east India, and from Tanganyika territory to Russian Turkistan on the north. This vast region would appear to be, on the whole, comprised of areas of comparatively low rainfall falling within or adjoining a great zone of desert and semi-desert country, stretching across North Africa and South Western and Central Asia. Based on the data of swarm movements studied by him, Uvarov has subdivided this vast region into the following five subregions, comprised of areas organically connected with one another from the point of view of the seasonal migrations of the locust:

(i) THE MOROCCAN—SENEGAMBIAN AREA: composed of Morocco, Rio-de-Oro, Senegambia and parts of western Sahara;

(ii) THE ALGERIAN—NIGERIAN AREA: comprising Algeria, Tunisia, Tripolitania and Cyrenaica in the north and the areas of French Sudan, French Niger Colony and Tchad Territory in the south, with the intervening area of Central Sahara;

(iii) THE SUDANESE—ARABIAN AREA: including Egypt, Anglo-Egyptian Sudan, Eritrea and Abyssinia, in Africa, and Arabia, Iraq, Trans-Jordan, Palestine, Syria and Turkey, in Asia;

(iv) THE SOUTH AFRICAN AREA: including South-West Africa and the northern parts of the Cape Province; and

(v) THE INDO-IRANIAN AREA: comprising the greater part of India, Afghanistan, Baluchistan, the central and eastern parts of Iran, Russian Turkmenistan and the south-eastern parts of Arabia.

It is probable that the Somali area along various parts of East Africa may form another distinct region.

There are certain rather striking characteristics, which are common to all these subregions. They consist mostly of rather dry, semi-desert and generally sandy areas, with rainfall ranging between five and ten inches during a year, and as a rule only sparsely covered with vegetation. Moreover, each distinct subregion comprises within its limits two types of geographical components, one of which is characterized by rainfall in winter and drought during the rest of the year and the other by summer rains and winter drought. A study of the activities of swarms during years of infestation has shown that locusts breed in spring in the winter-rain areas after satisfactory rainfall and that they breed again in summer in the summer-rain areas. In the Indo-Iranian region, where their activities have been studied by the writer, it has been observed that spring breeding takes place in areas of winter rainfall, such as Iran and many parts of Baluchistan and in parts of north-western India, and that the new generation produced in spring usually migrates eastwards into Sind, Punjab, Rajputana and United Province in early summer. With

the fall of monsoon rains, extensive breeding takes place in north-western India in summer and early autumn, and a considerable proportion of the swarms produced in summer usually migrates westwards into the western areas of winter rainfall during autumn and winter. These swarms usually over-winter in the south of Baluchistan and begin to breed in the spring months of the year following, in case sufficient rainfall is received. It is due to this regular sequence of a spring brood in winter rain areas followed by a seasonal migration into areas of summer rain and the occurrence of a summer brood during the monsoon rains, and ultimately of the migration of the brood produced here into the winter rain areas, that locust infestations are continued from one year to another. It is presumed that a similar system of seasonal migration followed by breeding prevails also in the other sub-regions during locust cycles.

In the Indo-Iranian subregion, it was also found that there are certain areas in both the winter rain and summer rain zones to which the solitary phase locusts are generally confined during periods of subsidence of the infestation, and even in these areas a similar system of alternate breeding, first in spring in the winter-rain belts and secondly, in summer in the summer-rain zones, was found to obtain. Such nuclei, which form the outbreak areas of the locust were discovered in the coastal region of British Mekran and in the desert areas of Sind and Rajputana. Similar outbreak areas have been found also in the other sub-regions of the Desert Locust in Africa and Asia.

The Indo-Iranian Region of Locust Incidence

Two very important central facts in the life economy of the Desert Locust in nature have emerged from studies carried out in the Indian area on its bionomics and field ecology, and they are: (i) its more or less absolute dependence on the occurrence of effective rainfall for oviposition and breeding and (ii) its inability under ordinary field conditions to live for more than six or seven months in the adult stage. Certain other locusts, as for instance *Patanga succincta* L. (the Bombay Locust) and *Nomadacris septemfasciata* Serv. (the Red Locust of Africa), have only a single annual generation and are able to pass the greater part of the year in the adult condition. On the other hand, in the case of the Desert Locust, Husain and Ahmad [1936] found that the total period of adult life ranged from 26·7 to 53·9 days on the average during the warmer months of the year but that the longevity of the adults was as high as 170·3 to 229·3 days in cases where over-wintering intervened. In two exceptional cases, Batra [*vide* p. 292] noted instances of adult longevity extending to 290 and 306 days respectively, but these also included the over-wintering period. As a rule, however, the adult life of the Desert Locust, under conditions prevailing in India is fairly short, and the species cannot in the ordinary course of events survive unless it passes through at least two generations in the year. Our observations in India have shown that it is able to achieve this, in the gregarious as well as in the solitary phase, by virtue of its ability to migrate long distances for purposes of breeding from winter-rain areas to those of summer rainfall, and *vice versa*, at the change of the seasons. The observations made above would appear to be applicable also to the solitary phase of the Migratory Locust (*Locusta migratoria* ph. *solitraia*) often found occurring in association with the Desert Locust in north-western India.

In ultimate analysis, the functioning of the Indo-Iranian region as a single unit of locust habitat is based on the circumstance that it is made up of two climatically different components which are complementary to

each other in respect of locust breeding enabling it to have, ordinarily, two generations in the year. It is, therefore, essential that the various characteristics of the different parts of this region should be examined in detail, for fully understanding their implications in a study of the locust problem in India.

General physiographical features

Geographically, the Indo-Iranian region is composed of, as already stated, (1) a western part comprising Baluchistan, Afghanistan, the central and eastern parts of Iran, and the south-eastern parts of the Arabian Peninsula, and (2) an eastern part including the various provinces and States of Northern India.

From the view point of physiography, the western area is made up of the Iranian Plateau, including Iran, Afghanistan and Baluchistan, and the low lying coastal strips stretching along the shores of the Gulf of Oman and the Persian Gulf in Baluchistan, Iran and the Oman Territory of Arabia. It is, on the whole a very hilly area. The eastern area lies entirely in India, consisting of the comparatively low plateau of Peninsular India, made up of Rajputana, Kathiawar, Central India and Central Province, and the great level plains of the Indo-Gangetic system encircling the Indian Peninsula to the west, north and east and separating it from the high ranges of the Himalayas and the hills of the Iranian Plateau.

Geologically, Peninsular India is very distinct both from the Indo-Gangetic alluvium and the extra-Peninsular areas, namely, the Himalayan ranges and the Iranian Plateau. It is an ancient land area, which has remained unsubmerged under the sea since early geological times. On the other hand, the extra-Peninsular area is comprised of regions which had remained under the sea until comparatively recent geological periods. In this area, the crust of the earth has apparently undergone considerable crumpling and folding, the hills upheaved thereby consisting of strata of marine origin.

The Indo-Gangetic plain is a very deep alluvium of comparatively very recent date, formed of extensive deposits of clay, loam or sand, washed down the sides of the Himalayan and other ranges by numerous rivers. The alluvial deposits mask, in reality, a deep trough along the foot of the hill-ranges, formed at the time of the elevation of the Himalayas, which had apparently functioned in parts as an arm of the sea till it was filled up by detritus from the hills.

(a) *Oro-relief and river systems*

(i) *The plains of Northern India.* The watershed between the Jumna and the Sutlej divides the alluvium of the Indus from that of the Ganges. The Punjab or the 'land of the five rivers'—the Sutlej, the Ravi, the Chenab, the Beas and the Jhelum—and the province of Sind, which may be described as the 'Gift of the Indus' together represent the valley of the Indus. while among the areas watered by the Ganges and the Brahmaputra and their tributaries are the United Provinces, Bihar, Bengal and Assam. These great plains form a vast level stretch of alluvium lying enclosed between the ranges of Baluchistan on the west, the mighty Himalayas on the north, the Burmese hills on the east and the great Peninsular block on the south. In the alluvial plains themselves, there are no hill ranges anywhere, except for the outcrops of the Khasi and Naga Hills in Assam and of the Raimahal Hills in south Bihar.

UNIVERSITY OF AGRICULTURAL SCIENCES
UNIVERSITY LIBRARY
BANGALORE-24.
4638

(ii) *Peninsular India.* The northern parts of this area form a low plateau, not more than 2,000 ft. above sea-level, and contain three main hill-ranges: (a) The Aravali Hills (with which the hills Sirohi, the Mount Abu range and the Mallani outcrops are organically connected) consist mostly of gneiss rocks and are geologically the oldest mountain range in India. They run south-west to north-east across the Rajputana area and end in the Ridge at Delhi. The highest point is about 5,600 ft. above sea-level on the Abu Range. (b) The Vindhya Hills form a low but long range of stratified rocks—slates and sandstones, stretching west to east across Central India. (c) The Western Ghats a long and fairly high range running south from the Tapti valley parallel to the West Coast of India. The tributaries of the Ganges, as well as the Narbada and the Tapti carry the drainage of the northern areas east of the Aravalis. West of these hills lies the vast stretch of country covered by the Great Indian or the Thar Desert. with its serried lines of high sand-dunes running from the Run of Cutch to Hissar. In this area there are no rivers, except for the Luni and its tributaries rising from the Aravalis, as the normally light rainfall is either absorbed or blocked up by the sand-dunes.

(iii) *The Iranian Plateau.* This is an elevated table-land 3,000 to 6,000 ft. high including various parts of Afghanistan, Baluchistan and Iran, bounded on the north by a more or less continuous circle of high mountains represented by the Karakoram, the Hindu-Kush, and the Parapomisus or the Koh-i-Baba ranges in Afghanistan, continued into Persia as the Kupeh-Dagh and Elburz Mountains, and along the south by a series of parallel, curved ranges of mountains, beginning from Sufed-Koh on the eastern borders of Afghanistan, and continued southwards as the Takht-i-Suleiman, the Toba Range, the Central Brahui Range, the Khirthar Range, the Mekran Central and Coastal Ranges into Baluchistan; westwards into Iranian Mekran as the Bampur Ranges; and thence north-westwards as the Zagros or the Western Iran Range, to meet the Caucasus Mountains.

Within the semi-circular arena enclosed by the afore-said northern and southern systems of hill-ranges, are situated several low-lying, land-locked basins of closed drainage, varying from 1,500 to 3,000 ft. height above sea-level. Of these, the most important are the Seistan basin receiving the drainage from the Helmand River system, the basin of Hamun-i-Mashkhel connected with the Mashkhel and the Rakhshan rivers, the Lora Hamun receiving the waters of the Pishin Lora and the great desert basins of Dasht-i-Lut and Dasht-i-Kavir. Besides the above rivers emptying themselves into such closed basins, there are a few others reaching the low-lying coastal plains, such as the Porali, the Hab, the Hingol, the Shadi Kaur, the Washt, and the Dashtiari (or Bahu Kaur).

In Baluchistan and Iran, as well as in east Arabia, there is a strip of low-lying coastal plain varying considerably in width, along the coasts of the Gulf of Oman, the Arabian Sea and the Persian Gulf. As this coastal strip contains certain sandy areas, known as 'reks', which are the favourite areas of habitat of the solitary locust, it is of considerable importance in a study of the locust problem.

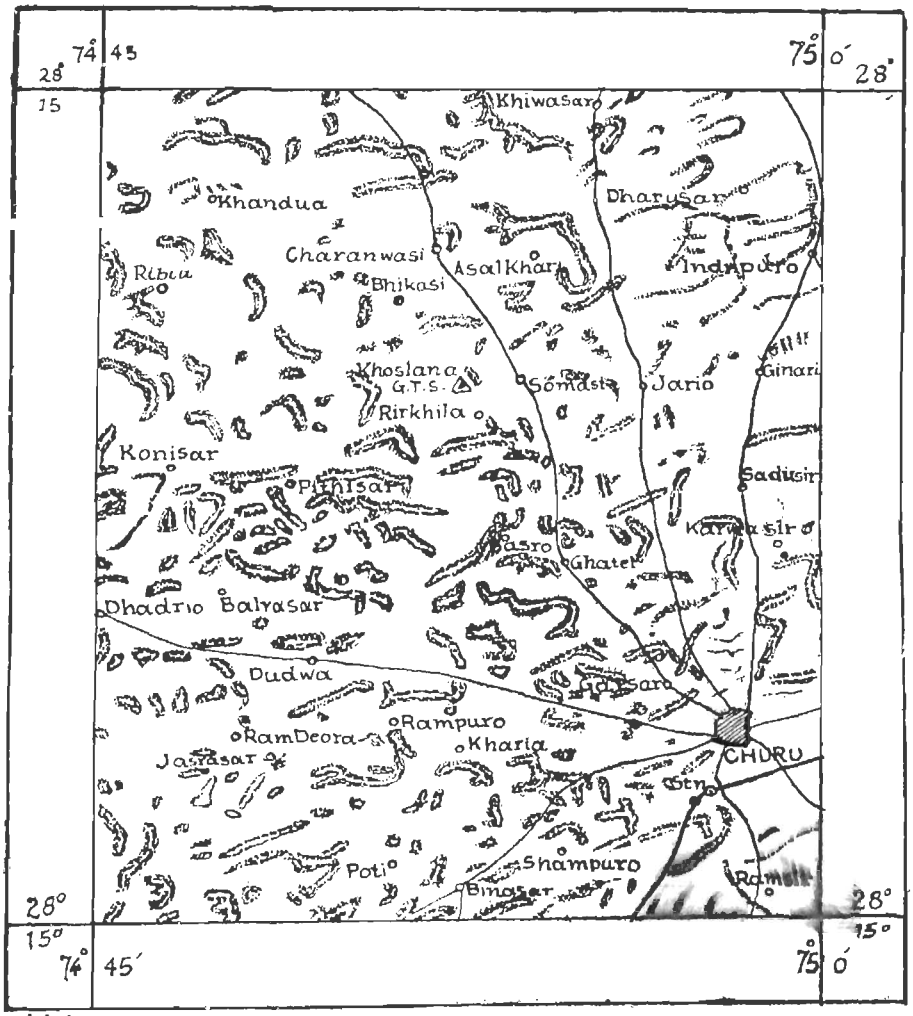
(b) *The soils*

A consideration of the soils of a tract is important from the point of view of locust ecology as on their character depend whether oviposition will occur and secondly whether the plants preferred by locusts will be available.

(i) *The Indo-Gangetic Plains.* As a general rule the soils are of an alluvial nature and are mostly loams, though all gradations between stiff

Text Figure 1]

NORTH EAST BIKANER AREA.



44.L.

AN AREA OF LOW, LOOSE, TRANSVERSE DUNES.

Plate 1.—*High sand-dunes in the Mallani area (near Bannor)*; dunes covered with grass and scattered *Acacia* trees. Various tall bushes in the foreground. The granite hill of Chohtan seen at the back of the dune. November, 1932.

clay and sandy loams may be found in places. In low lying waterlogged areas, the soils tend to become stiff clays, often impregnated with alkaline or neutral salts.

(ii) *Peninsular India.* In the central parts of the area, the soils vary from light alluvial loams to stiff red clays or black *regur*, depending on the locality. In the north-western parts, which are decidedly drier, sandy soils or sand accumulations are prominently observable. The Great Indian Desert, which forms the major part of the north-western areas of Peninsular India, will be dealt with in some detail further on.

(iii) *The Iranian Plateau.* In regard to this area, the writer is personally conversant with the conditions obtaining in Baluchistan only, but there is little doubt that conditions in the rest of the area are not much different. The elevated valleys situated between parallel ranges in the interior of the plateau are of the nature of long strips of level plains of fine silt 5 to 10 miles broad, flanked on either side by stretches of stony or gravelly detritus (*daman*), which gradually rises and merges with the sloping hill-sides. In certain valleys, which form closed basins, there is no outlet for the water washed down from the hills, and shallow sheets of water (known as '*Kap*') are formed during the rains in the centre of the plain, which dry up into dead level flats of fine clay in summer. The valleys of the plateau contain fertile soil and wherever flowing water is obtainable for irrigation, good cultivation is possible.

Owing to the general paucity of rainfall, there is a general tendency for the surface soils to become desiccated and disintegrated by wind action. All the lighter particles are lifted by the force of the wind and carried long distances to be deposited as dust or loess, while the comparatively heavier sand or silt particles are rolled along to form sand-mounds or sand-dunes [Cornish, 1897]. The existence of sandy soil or sand-mounds is of great importance in a study of locust epidemiology, as such areas are associated with egg-laying.

In areas of clayey loams, drift sand formation does not occur, for clay particles cling so tenaciously together that winds are unable to dislodge them, but in softer soils, especially in places where a surface flow of water has removed the clay particles, the wind sifts the sand grains from the surface soil and causes small mounds of sand or silt to accumulate. Sand drifts are specially noticeable along the banks of the larger water-courses and along the sea-beach. In the Chagai District and in the adjoining Kharan areas, there are good numbers of fairly large though isolated sand-dunes, while in the southern part of the Kharan State, there is an extensive desert covering an area of over 500 sq. miles, with large dunes—50 to 100 ft. high—, mostly drift-sand, almost bereft of vegetation, except for a few scattered bushes of *taghaz* (*Haloxylon ammodendron*, Bunge).

Rek areas. Along the coast of the Arabian Sea in British Mekran, certain extensive sand formations known locally as *reks* are met with. *Rek* signifies in Balochi 'a sandy area', but on the Mekran coast, the term is applied specially to certain peculiar undulating areas of sands, covered with fairly dense, scrub vegetation. These *reks* always occur along the sea-coast, being evidently derived from the beach sands. In many places on the Mekran coast, the sea-beach shelves down into the sea by gentle gradients, so that, at low tide, quite a considerable stretch of perfectly flat beach is exposed to the action of the strong south-west breeze, and the sand particles, as they get dry, are lifted and carried inland by the wind. During the prevalance of the south-west monsoon, there is very little rain on the Mekran coast, and the accumulation of drift sand is, generally, heavy and in the course of ages, the sands are

invaded by vegetation of a xerophytic type, which serves to bind and fix them. These *reks* are of considerable importance, as they constitute some of the favourite places of resort of the solitary phase locust.

Such *rek* formations are found occurring in favourable situations along the Mekran coast from Cape Monze (near Karachi) to Jiwani off the mouth of the Dasht River. The first stretch of *rek* begins from Naka Kharrari and extends up to Guruchela north of Sonmiani; the second from Khandewari up to Hingol; a third from Maniji Kaur east of Ormara to Rumra Kaur, with a break at Kalmat Hor; a fourth—the Pasni Reks—from Shadi Kaur to Chur Bandar; and a fifth stretching from Jabal Mehdi to Jiwani, inclusive of the *reks* of Gwadar, Akara, Pishukan and Jiwani. As the country along the coast in the Iran area across the border is very similar to that of the British area, it is presumed that such *reks* occur also in the Iranian territory, and indeed, Predtechensky has definitely recorded the existence of such areas along the coasts of the Arabian sea and the Persian Gulf, especially at Charbar, Jask, Bunder Abbas and Bushire [Predtechensky, 1935, 2].

In addition, small areas of wind blown sand are also seen in the interior valleys of Mekran and Lasbela, such as Kulanch, Kech and Panjgur, but these are made up of fine sand or silt particles derived from the surface of alluvial loams, and are decidedly different from the *reks* of sea beach origin. These are of peculiar interest, as many of the known cases of *incipient* swarming have been associated with *reks* derived from alluvial soils.

(c) *The Great Indian Desert*

The *Thar* or Great Indian Desert covers an enormous extent of area, taking the form of a broad arc nearly 500 miles long and 100 to 150 miles broad. It begins at the south-west corner of Sind from the borders of the Rann of Cutch and extends eastwards to the banks of the Luni River, and northwards to very near the banks of the Sutlej in Bahawalpur and the dry bed of the Ghaggar in Bikaner. Towards the north-east the desert reaches up to very near Hissar and Rewari. Although the whole of Rajputana west of the Aravali Range may be said to partake of the characters of a desert, the desert proper, i.e. the region of high sand-dunes is limited to a semi-circular area beginning from the Rann of Cutch, and comprising the areas of the *Thar* region of Sind, the Mallani, Sanchore, Sheo and Shergarh districts of Jodhpur, the areas of Jaisalmer and Khairpur, the greater part of Bahawalpur State, the Bikaner State with the exception of the Sri Ganganagar district, and the eastern parts of the Jaipur State. The Thar Desert is of particular interest as it forms one of the main areas of habitat of the solitary phase of the desert locust in India.

The general appearance of the Thar Desert has been aptly compared to that of 'the Atlantic Ocean during a severe storm'. Standing on the top of one of the numerous sand ridges of the desert, one may see a succession of sand dunes, range after range, as far as the eye can reach. The tallest dunes are to be found along the south western edge of the Thar Desert where they are 100 to 250 feet high on the average, the maximum height known being about 400 feet. The ridges are separated from one another by valleys of varying width. In some places, the neighbouring dunes are barely a furlong apart; in others, as in Chachro *taluka*, the valleys which form more or less flat sandy areas, may be two to three miles wide.

The various types of sand-dunes found in the Indian Desert are derived from the primitive *barchane* type. A typical *barchane* is semi lunar in shape, consisting of a convex body with two horns on either

side. The windward side, composed of the concave part of the crescent rises gradually in level till the crest of the dune is reached, beyond which there is a more or less abrupt drop on the leeward side. Sand dunes are the result of wind movements on loose soils. While strong winds carry the lighter particles long distances by lifting them up bodily into the air, they act on the heavier ones (such as grains of sand) which hug the ground, by pushing them forward by a process of rolling them one against the other. This usually results in a piling up of sand in an inclined plane up to the crest of the *barchane,* wherefrom sand-grains are dropped down the steep scarp. So long as the winds are strong and there is no rain, sandgrains keep moving steadily forward, and thereby the dunes as a whole are also kept moving, though at a very slow pace about 10 to 15 feet a year.

In the southern parts of the desert, where the winds are very strong, the originally formed *barchanes* had presumably been moving on, allowing the arms on either side to develop into long dunes. In the Thar, Mallani and Sanchor areas, the dunes often attain a length of 4 to 8 miles and usually run south west to north east. As a rule, adjacent parallel ridges tend ultimately to coalesce with each other and come to an abrupt end in a common steep scarp, 30 to 40 feet high, facing the north east. In many cases, new ridges may arise from the base of such scarps.

On the other hand, in the north eastern parts of the desert, the wind is not apparently strong enough to carry the load of sand to any considerable distance, so that the leeward scarps of adjoining dunes to coalesce together to form a transverse ridge running at right angles of the main wind direction, with an abrupt scarp facing the north-east (*vide* Fig.).

The origin of the desert. Various views had been held in the past in respect of the origin of the desert. Horace Bell [1888] considered the desert to have been the bed of a former sea, while Sir Bartle Frere [1870] thought that dunes were earth strata displaced during earthquakes. La Touche [1902] and Wadia [1919] were of opinion that the desert had been formed as a result of 'aeolian' action, the sand being mostly derived from disintegrated rock. On the other hand, Blanford [1876] and Medlicott and Blanford [1879] came to the conclusion that the sands of the desert had originated from the shores of great arms of the sea that had existed in post-tertiary times in the Sind Valley, in the Rann of Cutch and in the Luni Valley, a view which was fully endorsed by Oldham [1890]. The writer, who has had opportunities of examining all the important areas of the desert, is in a position to give full support to Blanford's conclusions.

The presence of Foraminiferan shells is one of the distinctive features of sands derived from the seashore, but in the case of ancient sands like those of the desert, there is no doubt that the calcareous matter of such shells had in the course of time been leached down into the subsoil to form the *kankar* beds common in the desert depressions.

The western edge of the Indian Desert runs parallel to the course of the Nara River, which takes off from the Indus near Rohri and runs down south to Ali Bunder, where it enters the Rann of Cutch. The Nara probably marks the eastern edge of a former gulf which flowed over the Indus valley in former ages. At the present day, the desert begins from the eastern bank of the Nara as a sandflat, which gradually rises in level until it becomes merged in a series of sand dunes that run across the desert, for over a hundred miles.

The sand-dunes of the Thar-Mallani area, comprising the southern desert, are, as already described, of the longitudinal kind and are particularly high (*vide* Plate 1). They are, moreover, of the fixed type of dunes, made up of fairly hard, well-set sand, resembling a loam in many of its characters. There is very little of moving sand in this region, except on the crest of the ridges and in parts of the valley beds. The sides of the dunes are, moreover, fairly well covered with perennial vegetation, mostly grass-clumps and bushes of desert plants, and in some parts also scattered trees like *Acacia* and *Salvadora*, and soon after rainfall, ephemeral vegetation, mainly grasses, springs up and covers the whole area.

On the other hand, the dunes in the central areas of the desert, such as those of the Pugal area in west Bikaner and Bikampur-Barsilpur areas of east Jaisalmer are generally of the fixed type, marked by the presence of a fair amount of permanent and temporary vegetational cover and fairly tall, but are mostly of the transverse type and contain a fairly high proportion of moving sand. Further east, as in the Sardarshahr, Reni and Sadulpur areas, the dunes (Fig. 1) are smaller and usually of the transverse type. Being mostly bare of vegetation and in great part made up of moving sand, they are, in fact, more of the *barchane* type.

As the railway track passes out of the desert northwards at Suratgarh, or eastwards at Siwani, one finds the dunes disappearing giving place to level areas, but the sand, however, is still seen everywhere. It covers the ground as a light mantle for considerable distances. Travelling north, one finds sandy soils with occasional sand mounds here and there common along the railway line in the Ferozepur, Bhatinda and Patiala areas, even up to the very foot of the outer Himalayas as near about Ambala. Eastwards, sands are met with not far from Delhi on the Rewari line, while a few low mounds are found in parts of the Muttra and Aligarh districts of the United Provinces. In fact, sand areas are noticeable even as far south as the Etawah district, where the sands have probably reached from the Karauli and Tonk areas.

Fixation of dunes. The main factor in the fixation of moving sand-dunes would appear to be rainfall. As is well known, sand absorbs most of the water that falls as rain, and very little of the rain runs off the sands until they become saturated. As the water sinks into the sand, it carries with it all the soluble matter, as well as much of the clay or colloidal particles present on the surface. With the gradual accumulation of saline and colloidal matter in the interior, the deeper layers of the dunes tend to become hard and compact, and when ultimately they become exposed by the gradual denudation of the looser surface layers by wind action, the dunes are hard enough to resist the disruptive action of strong winds. In other words, they become fixed. Another factor that favours this process is the appearance of surface vegetation, which in turn is dependent on rainfall. The root-system of plants growing on the dunes would, by their ramifications, bind up the sand and thus prevent it from being carried away by wind. It would thus appear that fixed dunes are definitely older than moving ones; the older the dunes, the harder their soil-exture. It follows, therefore, that the hardest dunes, situated in the southern regions of the desert, *viz.* Thar and Mallani, are the oldest and that the looser ones found in the north-eastern parts, i.e. in the Bikaner area, are the youngest. This would obviously indicate that the march of the sands has been in a south-west to north-east direction from the corner of the Rann towards the interior of India.

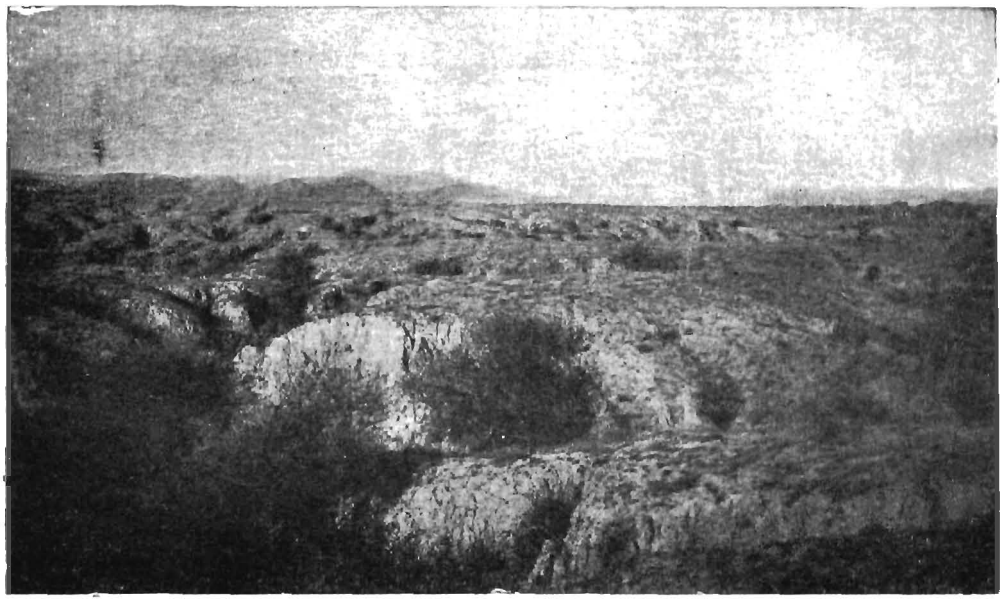


Plate 3.—*Bagar area of sandy loam soils in Lasbela State*.—A large belt of sandy loams stretches from the plains of the Porali to the sides of the Mor Range in Lasbela State. These soils were evidently formed of blown silt in the course of ages, and forms a vast area which is suitable for egg-laying after heavy rainfall. The motor track from Karachi to Sonmiani and Bela passes through a large part of this area. The soil and vegetation are somewhat similar to those of the old dune areas of the desert.

Plate 2.—*Pugal village on top of a sand-dune* August 1937 ; in western Bikaner; an area of undulating sand-dune country; Khejri trees (*Prosopis*) fairly common around village. Bushes in the foreground mostly Murt (*Panicum turgidum*) and Sinya (*Crotalaria burhia*).

Observations on the rate of movement of sands made at Pasni showed that, while the lighter particles of sand might be lifted up and carried over a fairly long distance by a violent wind, the heavier grains of sand can only progress by being rolled up one against the other. It was found in the case of one of the cusps (side ridges) of a *barchane* kept under observation; the rate of progress was about 15 feet during a year, while in the case of one of the large dunes, 100 to 150 ft. high, the rate of progression amounted only to about three to four a year. It was, moreover, obvious that the movements of dunes were more rapid in years of low rainfall than in those with good precipitation. On the whole, however, it is apparent that the rate of advance of sand-dunes can by no means be described as a rapid one, and, though, doubtless, it is dangerous to attempt a calculation of the probable age of the Indian Desert without more detailed data, it is obvious that it will have to be measured by geological rather than by historical time.

At present, the Indian Desert is by no means a real desert, covered as it is by a great mass of vegetation, which is specially dense after monsoon rainfall, and peopled as it is by great herds of cattle, sheep and camels, and a large though scattered human population. There is, in addition, a good deal of cultivation at the bottom of valleys, quickly maturing chops like *bajri* (*Pennisetum typhoides*) being grown with the help of the light rainfall received during the south west monsoon.

(d) *Other sandy areas*

Certain other large areas of sandy loams have also been met with in the course of locust surveys.

(i) *Lasbela area.* A great stretch of undulating sand loam soils (covering 400 to 500 sq. miles) is found to the east of a line from Uthal to Sonmiani, reaching up to the foot of the Mor and Pabb Ranges (*vide* pl. 3). As more than 10 miles of the motor track leading from Karachi to Bela passes through this area, a fairly good idea of the nature of this formation may be obtained by a journey along this track. The soil is fairly hard when dry, but soft when wet and is easily cut up by running water after heavy rainfall.

There is considerable evidence to show that the sea had extended far into the interior of the Porali valley in the past, and that the eastern shores of this ancient gulf had evidently furnished the sand or loess material of which the formation had been built up. The remarkable scrap observable along the Lak Baduk-Naka Kharrari section of the beach indicates that this area had been raised by an earth movement in the recent past.

This sand loam area is of much significance from the point of view of locust breeding, as it is well suited for oviposition, when it is thoroughly wetted by heavy rainfall, as had happened during the monsoon rains of 1926 and 1929.

(ii) *Gujarat area.* A similar, but far more extensive sand loam area occurs in north Gujarat, covering the greater part of the States of Radhanpur, Palanpur and Idar, the Mehsana district of Baroda State, and the districts of Ahmadabad and Viramgam. Another area occurs along the west coast of the Gulf of Cambay, including the districts of Nadiad, Cambay and Baroda. They are of the nature of undulating plains, some of the elevations, presenting an unmistakable resemblance to ancient sand-dunes. These areas gradually rise in elevation towards the north and east and ultimately abut against the foot of the Abu and Aravali ranges. Probably, these areas had originated from wind-blown sand or loess from the seabeach of the Sea of Cutch or from the shores of Gulf

of Cambay, under the very much drier conditions of a former age, and the present texture of the soil is obviously the result of the fixing action of the heavier rainfall of recent times.

(e) *The Kachhi plain*

The *Pat* area of Kachhi in Baluchistan is a great, treeless, level flat of fine clayish loam, composed mostly of alluvium and, possibly, partly of aeolian deposits of loess in places. It is virtually an extension of the Sind alluvium into a re-entrant of the Baluchistan highlands, wedged in between the Khirthar and Central Brahui ranges on the west and the hills of the Marri-Bugti country on the east. All the important streams of the valleys of Upper Baluchistan, such as the Mula, the Bolan and the Nari, debouch into the Kachhi area, and the flood waters disgorged by them after heavy rainfall on the hills scour through the country, and ultimately, such of the waters as are not utilized for cultivation get lost in the interior of the great desert plain.

In general, little rain falls on the Kachhi plain, but whenever any rainfall occurs, the rain-water drains off the level *pat* along shallow surface channels, which in many cases absorb much of the water as it flows. As these soils retain moisture for considerable periods when thoroughly soaked, the annuals that spring up on these channels, are kept green long after those on the *pat* have dried up, and as the soils are soft when moist, they afford suitable situations for oviposition by locusts. The Kachhi plain is, therefore, of much importance in studies of the locust problem in India.

CHAPTER II

CLIMATIC PECULIARITIES

STUDIES of the habits and activities of the Desert Locust have clearly indicated their dependence on weather. A short account of the climatic peculiarities of the Indo-Iranian region of locust habitat is therefore, given here in order to facilitate a correct understanding of the locust problem.

The two main divisions of the Indo-Iranian region, viz. the western or the Iranian Plateau area and the eastern or the Indian area, offer a greater contrast in their climatic peculiarities than even in their physical features. The western area is, in the main, characterized by a climate of the Mediterranean type with winter rainfall and summer drought, while the eastern area is predominantly one of the Monsoon type with summer rainfall and drought in winter and spring.

During periods of mass multiplication, swarms of the Desert Locust are known to have spread as far north as 42·5°N.Lat. in Russian Turkistan, and as far as 35°N.Lat. in Kashmir [Predtechensky, 1935] and to the south as far as 13°N.Lat. in South India. Within the limits of the Indo-Iranian region proper, the west to east range of the locust swarms extends from about 50°E. Long. to 96°E. Long. It should not be surprising that the enormous extent of country included within the above limits is composed of areas subject to a very wide range of meteorological conditions. The northern parts of the area of spread are, for instance, far too cold in general to be suited for locust activity except in summer, while the desert areas of Rajputana are, usually, far too dry in autumn and winter to function as locust habitats.

In regard to the solitary phase individuals of the Desert Locust, the northern limits of their habitat in the Indian areas would appear, so far as observed, to be about 33°N.Lat. in summer and about 28°N.Lat. in winter, while to the south, 22°N.Lat. is probably the southern limit.

The experimental data of Husain and Ahmad [1936] would indicate mean atmospheric temperature of 20° to 40°C. (68° to 104°F.) to be roughly the limits of favourable conditions for the survival of the eggs, hoppers and adults of *Schistocerca*. The authors have, however, not specified the humidity conditions under which the observations had been made. Hamilton [1936] working on the relation of humidity and temperature to the development of locusts found that the limits of survival of the hoppers and of the completion of the sexual maturation of adults of *Schistocerca* lay between the constants of 26° to 37° C. (80° to 100°F.) temperature and 45 to 80 per cent humidity. He found *Locusta* to be capable of tolerating combinations of somewhat higher temperatures and relative humidity.

It is also fairly evident that the Desert Locust is not able to tolerate atmospheric humidity beyond certain limits. In very humid climates with relative atmospheric humidity of 90 per cent and above, the locust succumbs to disease, while under conditions of low atmospheric humidity (for instance, 30 per cent and below) it apparently feels much discomfort, and generally flees from them sooner or later. Lean [1931] has shown that swarms of *Locusta migratoria migratorioides* were most active in

Nigeria within the limits of 40 and 85 per cent relative humidity, and studies of locust movements in India would in general appear to support this conclusion.

In connection with a study of the general ecology of the Desert Locust in its gregarious condition, Bodenheimer [1932] divided the regions subject to the invasions of the locust into various 'Climatypes' according to their respective range of monthly mean temperatures, of which, however, he considered two to be specially important, viz. 'The Sudan-Deccan type' with monthly mean temperature range of 20° to 30°C. (68° to 86°F.), representing the permanent breeding grounds of the locust and the Sahara-Sind subregion, with a monthly mean range of 10° to 30°C. (50° to 86°F.), representing the region where the mass multiplication generally occurs. He was of the opinion that the *solitaria* type was generally confined to Sudan-Deccan subregion, having only a single brood in summer with an adult diapause during the rest of the year, and that in years of high multiplication, the *solitaria* population migrated to the fringes of the neighbouring Sahara-Sind climatype and underwent crowded breeding therein.

There is, thus, a consensus of opinion that a breeding of the Desert Locust would be possible only in such areas and at such times as may be characterized roughly by a temperature range of 20° to 30°C. and a relative humidity range of 45 to 80 per cent. In evaluating the importance of any particular area with regard to its suitability as locust habitat, therefore, the above points should be kept in view.

Climatic analysis. The climate of an area can be estimated by the following factors: (i) temperature and its range of variation as affected by circumstances of latitude and altitude and by variations of local insolation; (ii) atmospheric and soil humidity, as affected by incidence of rainfall and by maritime influence; and (iii) variations of barometric pressure and their effect on air movements.

In considering the climatic peculiarities of the locust habitat in the Indo-Iranian region, it would be convenient to deal with the Western and Eastern parts of the region separately, as they are markedly different.

(a) *The Western area*

This area is composed of (i) the Iranian Plateau with the central basins and (ii) the Lowland Plains, consisting of the coastal areas of British and Iranian Mekran and south-east Arabia, adjoining the Arabian Sea, the Gulf of Oman and the Persian Gulf.

The temperature of the Iranian Plateau depends on the latitude and the altitude of its component parts. Elevations above 3,000 ft. may be said in general to be unsuitable as a locust habitat except in summer. The central basins, which are only about 1,500 to 3,000 ft. in height, are warmer than the uplands, but owing to their general desiccation, they do not function as breeding grounds, except in rare cases. In regard to the Iranian part of the plateau, Predtechensky [1935,] has given an excellent detailed description of the climate of the different areas, which can apply to appropriate parts of British Baluchistan also as it is comprised of very similar tracts of country. The coastal plains enjoy milder winters and cooler summers than the areas of the hinterland, due to the moderating influence of the sea. Except when the land-breezes prevail, the coastal areas are generally more humid.

The predominant characteristic of the western area, however, is that it falls within the zone of winter rains. The major part of its scanty annual rainfall (five to ten inches on the average) is received in the course of the passage of what are known as 'western disturbances' during the period, November to April.

UAS LIBRARY GKVK
G-4638

Western disturbances. In view of the important bearing these disturbances have on the study of locust epidemiology, a brief account of the nature of these winter depressions would be useful.

As the sun moves south to its winter solstice, the zone of high parometric pressures in Central Asia gradually moves down till the areas of Iran, Baluchistan and North-west India become included in a tongue of high pressure projecting southwards. The zone of low pressures at the same time passes south of the equator. In the western area, the general direction of the wind in winter is north-easterly, a characteristic feature of the Central Asian anticyclone.

Generally, however, in north temperate climates, the descent of cold polar air from the north provokes a rush of warm equatorial air in the opposite direction, and the consequence is the formation of various depressions in temperate latitudes at the meeting place of the northern and southern air currents. These depressions or disturbances generally originate on the Atlantic sea-board of Europe and travel west to east towards the Mediterranean, and thence across Iraq and Iran up to northern India. A single depression may not travel far, but as it dies down, it may give rise to new ones, which would march further east as they form. The western disturbances that are observed in the Indo-Iranian region would appear to originate in the eastern part of the Mediterranean and to travel gradually across Iraq, the Persian Gulf, Iran, Baluchistan and the North-west Frontier Province, ultimately reaching the Punjab and Kashmir, and breaking up in the Himalayan Ranges. Others may travel from the Punjab and the Rajputana areas, across the United Provinces, Central Province and Bengal into Assam and the Eastern Himalayas (*vide* pl. 7).

The winter depressions represent the result of a conflict between the cold polar air and a warm maritime current from more southerly latitudes, and a certain amount of regularity is observable in their development and progress. The first indication of the approach of a disturbance is the appearance of fine cirrus or cirro-stratus clouds very high up in the sky, often lending themselves to the development of magnificent sunsets. The temperature then rises, indicating the descent of warm moist air to ground level (the 'warm front stage'), followed by the appearance of heavy clouds and a change in the wind direction. This is followed by the 'cold front stage', when the warm air mass is again replaced by a cold one, as signalled by a change of wind direction and the occurrence of convectional disturbances resulting in squalls and storms, often accompanied by heavy rainfall, [Banerji, 1931].

The winter disturbances generally travel rapidly and may within a week or ten days of leaving Iraq, pass over Iran, Baluchistan and North West India, reach the confines of North East India. At any particular place, the disturbance does not last beyond two or three days. During his visits to Mekran in the course of six years, the writer had many opportunities of observing the progress of several disturbances at close quarters. The following may be taken as a typical instance of the progress of one of them. During his last visit to Pasni in February, 1938, he noted the appearance of cirrus clouds on the 3rd February and the wind then blowing was a westerly one. By the morning of the 4th, however, it had changed to an easterly one, and during the afternoon it was south-easterly. The whole of the day, the sky was overcast, and there was a light drizzle at mid-day, but by nightfall, the sky had greatly cleared up. Towards midnight, however, clouds had gathered again, and a north-westerly wind set in. There was much lightning and thunder and by 2 A.M. on the morning of the 5th, there was a heavy downpour of rain amounting to 1·36 inches. By 6 A.M. the sky was clear and a strong 'Goreech' or cold north easterly wind was blowing.

Although 50 to 55 western disturbances regularly appear in the Indo-Iranian region every year between October and May, it is only a few of them that develop into active storms and give general rainfall. A great many of them, especially the earlier and the later ones, may prove to be sterile storms that merely raise huge quantities of dust as they pass on. The depressions usually manifest themselves at the southern edge of the zone of high pressures, and it is only during December, January and February when the zone reaches farthest south, that heavy rainfall occurs in the regions of Mekran and Muscat, and by March and April when the high pressures begin to retreat northward, the chances of rain are greater in the interior, as for instance in Upper Baluchistan, the North-West Frontier Province and Kashmir.

In certain years, it may be noted, most of the disturbances prove to be barren of rainfall, right from Iraq down to northern India, while in certain others, particular sections, such as the Persian Gulf, Mekran or Upper Baluchistan, receive a fair amount of rainfall, while the rest may not. It is presumed that such rainfall defect is due to peculiarities in the distribution of barometric pressures of such years. So far as British Baluchistan is concerned, it is interesting to note (as may be seen from the statement given below) that, during the period 1920 to 1938, there have been partial or complete failures of winter rainfall during the winter period of 1920-21, 1928-29 (in which a good fall in November 1928 was followed by drought during the following months), 1931-32, 1933-34, and 1936-37 in the Mekran area, showing that one might expect drought here once in three or four years. Though generally, the incidence of rainfall or drought in Mekran directly corresponds with that in Upper Baluchistan, in certain years, e.g., 1928-29 and 1936-37, good rainfall occurred in Upper Baluchistan, despite a failure in Mekran.

Statement of total rainfall received during the winter months from November to May

Winter periods	Pasni	Panjgur	Quetta
1919-20	5·36	2·93	5·78
1920-21*	0·28	0·02	1·65
1921-22	5·66	5·16	7·69
1922-23	2·87	1·54	7·30
1923-24*	12·17	3·83	8·84
1924-25*	1·50	1·51	4·56
1925-26	8·06	5·78	9·58
1926-27	3·36	3·22	4·79
1927-28	4·15	2·58	7·86
1928-29*	4·84	1·85	6·30
1929-30	9·48	5·45	9·05
1930-31	5·71	2·90	10·99
1931-32*	0·98	1·30	3·28
1932-33	12·09	5·30	6·94
1933-34*	0·66	0·50	2·84
1934-35	11·44	9·60	13·27
1935-36	3·25	4·01	7·66
1936-37*	1·23	2·87	11·78
1937-38	4·08	1·60	9·48
1938-39	10·23	5·16	13·15

*Denotes a year of drought.

Pasni is taken as a type for the Mekran coastal region;
Panjgur, as a type for the hinter-land of Mekran ; and
Quetta as a type for the uplands of Baluchistan.

The rainfall regime of the Red Sea areas. Experience obtained in the Indo-Iranian region, as well as information gathered from the published accounts of locust breeding in the outbreak centres on the Red Sea coasts [Johnston, 1926; Maxwell-Darling, 1936] indicates the great importance of winter rainfall in the transformation of the *solitaria* phase into *gregaria*. As already mentioned, the rainfall in the regions of Iran, Baluchistan and eastern Arabia is associated with winter depressions of the Mediterranean type. As far as can be gathered from the account of the meteorological conditions of the Red Sea area in the *"Red Sea Pilot"* [1932], this area is almost beyond the influence of the barometric depressions of temperate latitudes, which tend to follow the northern shores of the eastern Mediterranean. The northern half of the Red Sea is practically rainless. Southward of latitude 20°N., the winter rains commence very early, i.e. about October and continue intermittently till February. The prevailing wind direction is S.S.E. in this area from October to May. This is coincident with the development of the north east winds in the Indian seas from October onwards, and since it is stated that the N.E. direction of these winds changes into S.S.E. after entering the Straits of Bab-el-Mandeb, it is probable that the winter rainfall of the Red Sea is connected with the movements of the North-East Monsoon across the Arabian Sea. While the winter breeding in the Persian Gulf areas is influenced by rains originating from the west, the Red Sea areas are dependent on rains coming from the east. Apparently, therefore, one should not expect, as a rule, any synchronization of heavy rainfall in these two outbreak areas, as they are subject to different meteorological influences.

Conditions in summer. By the middle of May, the western depressions gradually tend to disappear, and the weather rapidly becomes dry and hot, especially in the interior of the country. In the western parts of Baluchistan, extremely dry and hot northwest winds from the direction of Iran begin to prevail in May and bring about a condition of high desiccation. On the coastal plains, however, the south-west winds from the sea, presumably a part of the deflected monsoon current, prevail between May and September and serve to keep the temperatures comparatively low and the humidity high. This is a point of much significance from the point of view of locust ecology.

Usually, there is little rainfall during summer, but the eastern parts of Baluchistan may come under the influence of some of the depressions of the Bay of Bengal or the Arabian Sea, so that as a rule Lasbela, Jhalawan, Kolwa, Kachhi, Loralai and Zhob get a fair amount of rain (varying from one to five inches) during the summer months. In certain years the rainfall may extend along the Kech and Panjgur valleys up to the borders of Iran, and sometimes cyclones along the Mekran coast may cause heavy rainfall on the coastal areas, as for instance, 7·32 inches recorded in June 1914, 5·15 inches in July 1930 and 5·69 inches in July 1932 at Pasni.

(b) *The Eastern or Indian Area*

The area comprises the northern part of the Indian Peninsula, the Indo-Gangetic Plains, and a few hilly areas such as Kashmir and the North West Frontier Province. The parts subject to the invasions of the locust lie above 22°N. Lat. and most of them except Kashmir are below 2,000 ft. in altitude. The winter is not generally severe except to the north of Lat. 28°N., and as a rule low temperatures are not reached except when a cold wave sets in and chilly north winds prevail. In the dry season, temperatures rise rapidly from April onwards all over northern India, and

in Upper Sind and Kachhi, the hottest parts of India, maxima ranging from 110°F. to 125°F. may be recorded day after day during May and June. With the burst of the monsoon, the heat abates in many places, though Upper Sind continues to record high temperatures throughout summer.

Except in the coastal districts, humidity is very low all over the country during the dry season (March to June), but with the advent of the monsoon winds by the middle of May and their gradual penetration into the interior, there is a progressive increase of humidity, leading to the highly moist conditions of the rainy season. In the Rajputana desert areas, similarly, a gradual rise of humidity from the coast into the interior is clearly observable from May onwards. Thus, during May, Jodhpur and Barmer, which are situated in the southern half of the desert, record 50 to 60 per cent of humidity, while Bikaner, situated further north, records much lower percentages; whereas, by June, conditions of fairly high humidity prevail in Bikaner also.

Monsoon rainfall. The great characteristic of the Indian area is the occurrence of summer rainfall due to the influence of the South-West Monsoon.

The return of the sun to the northern hemisphere by March, leads to a gradual shift in the distribution of atmospheric pressures. The zone of high pressures begins to retreat northward from the Punjab and Baluchistan, and the low pressure area gradually advances from the equatorial regions till it establishes itself in the region of Upper Sind and Baluchistan during the summer period. By May, the south-east trade winds of the southern hemisphere gradually strengthen and cross the equator to form the current of the South-West Monsoon, which generally bursts on the coast of Ceylon by the end of May and on the west coast of India by the beginning of June. The monsoon current becomes divided in the Indian area into (i) *the Arabian Sea branch,* which passes over the Western Ghats and gives extensive rainfall to the greater part of the Peninsula, including the Deccan, Gujarat, the Central Provinces and parts of Central India, and (ii) the *Bay of Bengal branch,* which advances northwards across the Bay. Part of this current passes into Burma, but the rest of it strikes against the lofty ranges to the east and the north of the head of the bay and is deflected by them westwards into the Gangetic Valley. Normally the Bay current supplies rainfall only to Bengal, Behar and the United Provinces, but, if specially strong, it reaches Rajputana and the Punjab also.

It is, however, by the agency of a system of storms and depressions developing along a trough of low pressure, extending from Orissa to North-West India (*vide* Pl. 5), and marking the line of contact between the direct current across the Peninsula and the deflected Bay current over the Gangetic Plain, that an effective extension of monsoon rainfall into the dry areas of North-Western India takes place.

These depressions originate generally in the north of the Bay of Bengal, and after intensifying, often into storms of a cyclonic character, cross the coast between Orissa and western Bengal and rapidly pass progressively north-westwards over Chota Nagpur, the Central Provinces, Central India and Rajputana, usually reaching as far as Sind and Punjab before they break up. During a week monsoon, the Bay current tends to discharge most of its moisture content in the eastern parts of India and the Himalayan foot-hills, to the disadvantage of the western parts of the plains. When depressions are formed, their dynamics furnish the monsoon current with the energy needed for carrying rainfall to distant areas like the Punjab, Sind and Baluchistan. They also serve to

cause heavy bursts of rainfall along the tracks they traverse, and at times whip up the flagging energies of the monsoon by quickening the wind circulation.

The importance of the depressions coming from the Bay of Bengal in regard to the life-economy of the locust cannot be over-estimated, since in the desert regions of Sind and Rajputana, the advent of rain on which locusts are dependent for obtaining their food plants and for breeding, is almost entirely contingent on their arrival. In the desert area, the dominant wind during the monsoon months is from the south-west, and although it is fairly humid and makes life bearable in the desert and although it may be often accompanied by heavy clouds that may overcast the sky, it causes but little rainfall. It is only when the wind-direction changes, and easterly or north easterly winds accompanied by thunder and lightning and squally weather appear, indicating the approach of one of the Bay depressions, that heavy rains are received. Such changes in the wind direction have been found to be of much significance in studies of locust migrations.

The intensity of rainfall received in the desert is very rarely uniform; the falls are often merely local. In many cases the rainfall is restricted to tracks along which particular depressions or storms happen to pass. In the southern parts of the desert area, *e.g.*, the Thar-Mallani region, good falls may sometimes be caused by storms formed in the Arabian Sea off the Kathiawar Coast in the course of their passage *via* Kathiawar and Cutch into Sind and Baluchistan. The Jaisalmer area, especially the north-western part adjoining Sind, is the least favoured from the point of view of rainfall, as it is out of the way of the general course of the Bay depressions. Its average rainfall is only about five or six inches, during the year. In the southern parts of the desert, especially, the Sanchor district and the Nagar Parkar taluka of Sind the annual fall averages about 20 inches, while in the case of the country bordering the Aravali and Abu ranges it is even heavier. On the whole, the average annual rainfall in the Indian Desert may be taken to vary from 6 to 20 inches.

Fluctuation of temperature and humidity in the desert. As compared with the coastal areas, the interior of the desert is subject to great extremes of temperature variation. Along the coast, as a result of the moderating influence of the sea, the summers are relatively cool and moist, while the winters are comparatively warm and mild. In the interior of the desert, on the other hand, low temperatures are brought about in winter by the extensive loss of heat by radiation at night, while during May and June, owing to the absorption of solar heat by sand, very high diurnal temperatures are experienced. With the advent of the monsoon and the consequent prevalence of clouded skies and the occurrence of fairly general precipitation, the heat is greatly alleviated. The monsoon months are, on the whole, cool and moist and life is not at all unpleasant in the Indian Desert at this period.

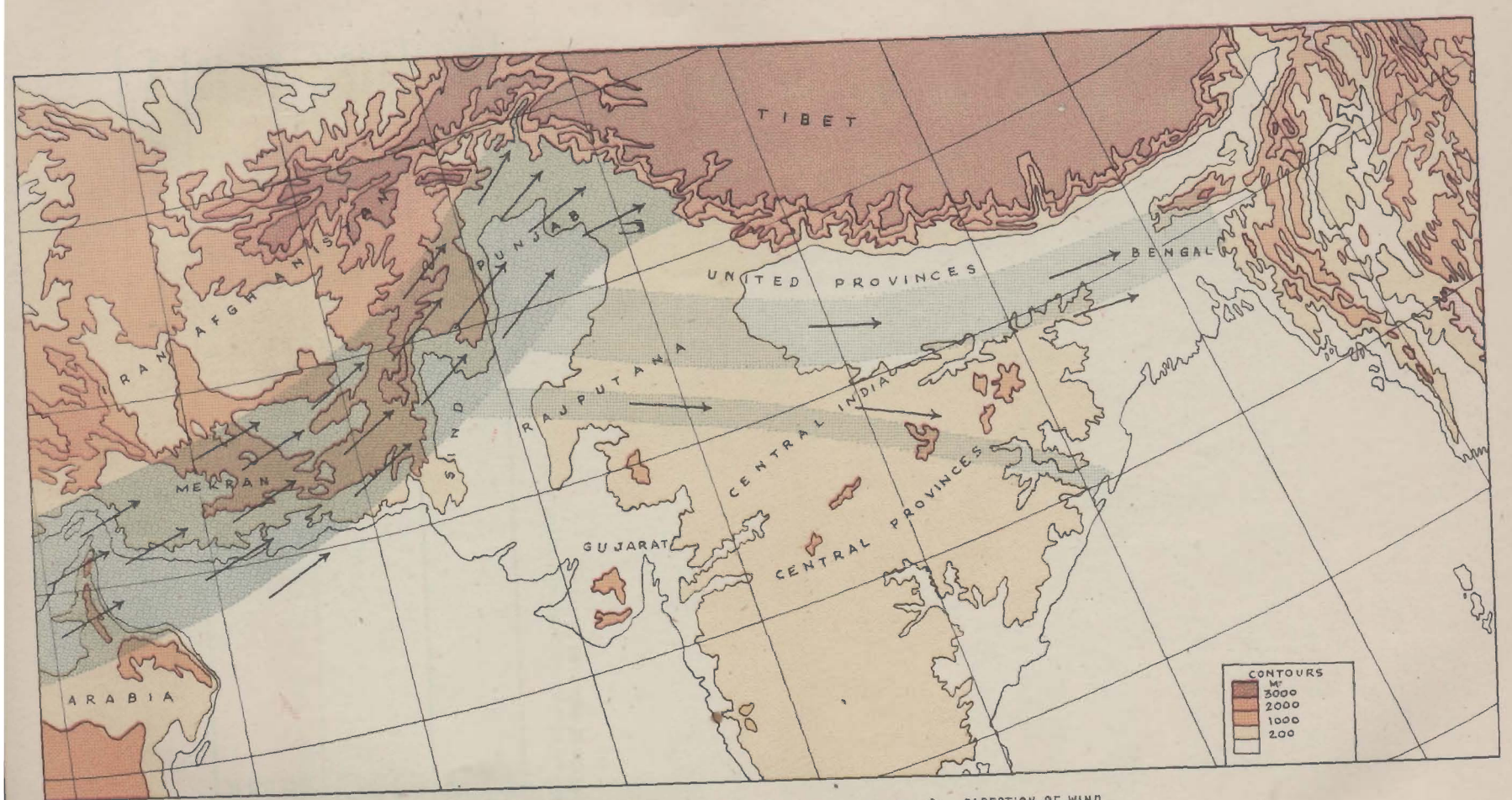
By the middle of September, the monsoon usually withdraws from north western India, and as a result, the skies are clear and the days are hot once again. During September-October, there is, therefore, a distinct rise in the maximum temperatures. At the same time, there is a definite fall in atmospheric humidity. As dry winds often prevail at this part of the year in the desert, conditions of high saturation deficiency are brought about, which react on the ecological requirements of the locust and generally causes it to migrate.

Frequency of drought or heavy rainfall in the desert. Studies of locust ecology in the desert areas have shown that locust breeding, whether in the *gregaria* or *solitaria* phase, is entirely dependent on the character of the rainfall. In years when the rains are copious and prolonged, the locust is able to pass through two successive generations in the monsoon season, thereby bringing about a rapid increase of population. In case rainfall is restricted to particular parts of the desert, locusts are often able to reach such areas by migration and breed there. On the other hand, if the drought be general, there would be little or no reproduction and a decrease of population is inevitable.

The monthly rainfall data for the Indian Desert during the monsoon period, (May to September) were examined for a series of years (1899 to 1938) with the object of working out the frequency of years of drought and good rainfall. Four different stations were selected as representative of the different parts of the desert: Chachro for the southern, Jodhpur for the central, and Bikaner for the northern, and Hissar for the north-eastern fringe. It may be seen from the statement appended, that there have been more or less general failures of rain during 1899, 1911, 1918 and 1939, and partial droughts in 1901, 1904, 1905, 1915, 1925, 1930 and 1938. Heavy or fairly heavy general rainfall occurred in the following years: 1900, 1903, 1907, 1908, 1909, 1916, 1917, 1921, 1924, 1926, 1927, 1929, 1931, 1933 and 1936. One may, thus, expect in the desert, roughly, about one year of drought, complete or partial, in four years, and one year of fairly good rain in three.

Statement showing the total rainfall during the monsoon period (May to September) in Sind-Rajputana desert areas from 1899 *to* 1939
(Rainfall in inches)

Years	Chachro	Jodhpur	Bikaner	Hissar
1899**	0·09	0·96	1·14	2·21
1900.	13·10	15·37	8·57	5·48
1901*	0·75	7·90	5·42	6·42
1902	10·75	6·89	5·67	9·36
1903	8·79	19·81	10·00	16·60
1904*	2·68	5·94	5·68	11·26
1905*	7·89	3·09	2·32	9·87
1906	10·96	8·88	7·76	10·05
1907	9·29	10·04	18·64	18·05
1908	23·20	35·32	17·09	22·30
1909	9·92	21·36	20·94	18·39
1910	6·71	10·17	12·81	13·21
1911**	2·50	6·09	29·57	9·27
1912	8·21	14·71	4·97	7·73
1913	26·52	6·82	4·74	9·06
1914	15·57	9·56	11·98	17·75
1915*	3·34	2·86	2·67	6·57
1916	27·25	25·78	18·68	20·08
1917	18·92	34·62	16·01	26·81
1918**	1·85	1·16	1·06	6·83
1919	11·00	7·55	17·05	9·05
1920	5·28	11·17	12·19	6·70
1921	18·49	6·97	16·22	11·00
1922	7·79	10·42	8·81	16·55
1923	4.45	15·65	10·91	19·85
1924	15·59	20·77	6·93	5·91
1925*	4·92	4·80	6·59	11·38



TRACKS OF WESTERN DISTURBANCES.

DIRECTION OF WIND.

GENERAL TRACK OF WINTER WESTERN DISTURBANCES

DECEMBER-MARCH

Years	Chachro	Jodhpur	Bikaner	Hissar
1926	17·81	18·30	11·27	25·92
1927	19·35	20·00	8·78	12·47
1928	4·86	11·82	11·68	12·49
1929	21·59	10·26	9·79	6·70
1930*	3·76	8·13	8·47	16·86
1931	12·95	16·56	11·08	14·43
1932	9·28	16·57	8·07	7·97
1933	10·44	22·43	16·42	21·78
1934	6·97	14·97	16·28	10·77
1935	11·14	9·46	11·36	16·0
1936	6·22	9·66	18·88	7·27
1937	8·66	10·06	9·71	16·87
1938*	7·82	10·26	4·66	4·03
1939**	4·52	5·86	2·45	6·93

**Year of severe drought all over the desert.
*Year of deficiency of rain.

CHAPTER III

VEGETATIONAL CHARACTERISTICS

THE character of the vegetation of an area is of the utmost importance in determining its suitability as a habitat of the desert locust. It is essential that the vegetation should not only comprise such species as are the preferred food-plants of the locust, but should be of such a nature as to afford it shelter from enemies and from the inclemencies of weather. The desert locust is a lover of sunlight and generally prefers to sit during day-time on open ground between bushes, unless it be too hot or too chilly. At night it usually retires to the base or inside of bushes. Under ordinary circumstances, therefore, it shows a distinct preference to scrub vegetation. Dense forest or thick jungle is generally avoided by the solitary phase.

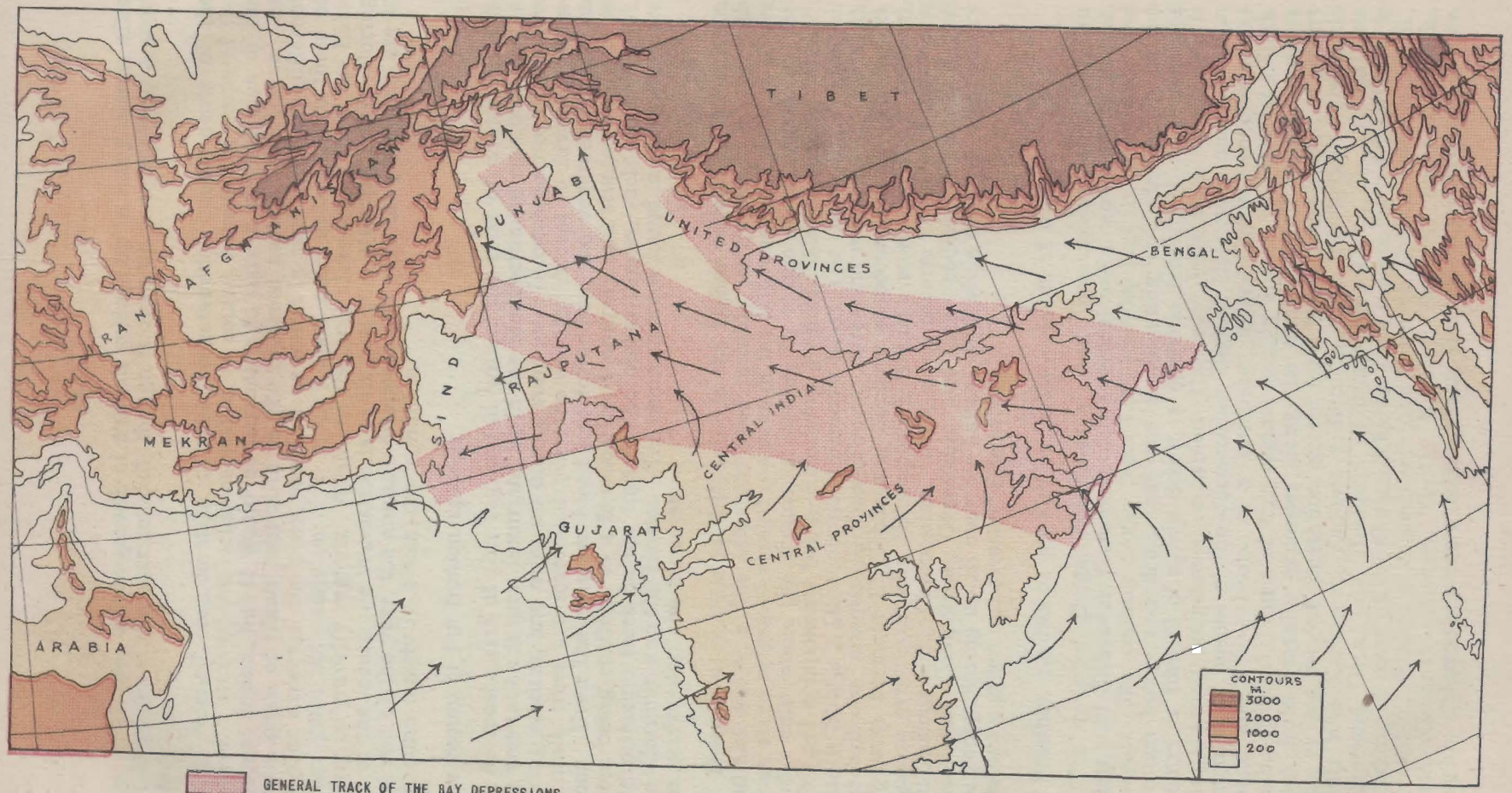
From the point of view of vegetation, the Indo-Iranian region of locust habitat may be divided into (i) the Iranian upland area, (ii) the coastal areas of Iran, Baluchistan and eastern Arabia, and (iii) the areas of North-Western India.

According to Hooker and Thomson, the Indian Flora includes very few genera or species peculiar to India, and is rather a mixture of various types of plants which had in course of time migrated into it from neighbouring countries, as for example from Malaya, Tibet and China, and from Central Asia [Hooker and Thomson, 1855]. Hooker [1907] is of opinion that the Flora of British Baluchistan is mostly Oriental (i.e. of the Middle East or Levantine type) with an admixture of Himalayan and Indian plants (i.e. of European and Indo-African types), while the flora of the lower levels of Baluchistan is stated to be 'more Arabic-Persian'. According to Burkill [1909], the flora of Baluchistan is Persian in character, but very much less northern than that of Afghanistan.

The flora of the Iranian Plateau would appear, therefore, to be mostly a mixture of European and Oriental (Middle East) types, and that of the coastal areas to contain more of the Arabian and African types. In this connection, Predtechensky [1935, 2] observes in regard to the southern parts of Iran, 'the hot regions of southern Persia contain several representatives of Indian and Africo-Arabian flora and fauna. The representatives of the flora and fauna of Anatolia, Turan and Iran proper are for the most part limited to the more northern or colder climates only'.

The flora of the 'Indus Plain Region' of Hooker, including Punjab, Sind, North Gujarat, Cutch, and Rajputana west of the Aravalis is described by him as 'a low, chiefly herbaceous vegetation of plants common to most parts of India, mixed with Oriental, African and European types, with thickets of shrubs and a few trees'.

In correspondence with the general aridity of the regions forming the habitat of the desert locust, and the low rainfall (five to ten inches during the year on the average), the vegetation, is, on the whole, very sparse. The only places where high and dense natural vegetation can be found are along the flanks of the Aravalis on the east, and the foothills of the Punjab Himalayas on the north. Westwards of the Aravalis and southwards of the Punjab hills, the vegetation gradually diminishes in density and size, and among the sand-dunes of parts of the desert, the ground may be absolutely bare during the dry season. Even among the valleys of the uplands of Baluchistan, trees are scarce and may be seen only along the banks of streams or in cultivated areas. Most parts of the locust habitat are characterized by stunted trees, and bush or scrub vegetation,



GENERAL TRACK OF THE BAY DEPRESSIONS.

GENERAL DIRECTION OF DOMINANT WINDS.

GENERAL TRACK OF DEPRESSIONS OF THE BAY BRANCH OF THE MONSOON

JUNE-SEPTEMBER

but, in general, a lush-growth of annuals springs up in many places, after good spring or summer rainfall, though it dries up completely in a short time.

A detailed consideration of the vegetational components of the different areas of the locust habitat is, of course, beyond the scope of the present report, but it would be necessary to have a general idea of the main types of plants met with in the different parts of the region. As may be expected, the plant associations found in sand areas are different from those noticeable on clay or clay loam soils, as also from those of stony or gravelly regions. Again, in the arid areas which form the habitat of the locust, the vegetation is at its best just after the rains. During the rest of the year, the annuals disappear and even the perennials are to be found mostly in a semi-dry condition.

The region of the Iranian uplands

As most parts of this region fall within the zone of winter rainfall, the vegetation is most luxuriant, as in the Mediterranean countries, in the spring months, and dries up during summer. In consequence of the low rainfall, trees are scarce all over the country except in favoured situations. Even the hills are bleak and forbidding, the vegetation found on them being confined to a few scattered junipers and stunted wild olive and pistachio trees on the tops of the higher ranges, such as the Ziarat, the Zarghun and the Harboi. The common trees found in the valleys are the poplar and the tamarisk.

There is very little of drift sand in the higher valleys of Baluchistan, and the soil is a fine alluvium (and possibly partly loess), mixed with much stone or gravel along the flanks of the hill-ranges. Except in places under cultivation, the ground is covered by a thin scrub vegetation, the principal components being *Haloxylon griffithii* Bunge, (Brahui 'Bundi', Pashtu 'Shorae'), *Othonnopsis intermedia* Boiss., (Br. 'Manguli', P. 'Gangu') *Chrozophora obliqua* A. Juss (Popat), *Artemisia maritima* L. (Tirakh), *Peganum harmala* L. (Ispantan), *Sophora alopecuroides* L. (Busundak), *Sophora griffithi* Stocks, (Shampastir), *Alhagi camelorum* Fisch., (Shinz), and various spiny Compositae. After rains, several annuals of the orders Cruciferae, Compositae, Gramineae and Chenopodiaceae, including also one poppy, spring up all over the valleys, and while they last, the country presents a green and pleasant appearance.

Possibly, conditions are similar in the uplands of Iran.

The areas of Chagai and Kharan, and presumably the Registan country of Kandahar, form part of the central basin region of the Iranian Plateau. The country varies from 1,500 to 4,000 feet in its altitude, and is much hotter and drier than the surrounding uplands. Much of the country is formed of sandy desert, a common feature of the landscape being moving sand-dunes, on which the only vegetation noticeable is composed of bushes of the deep-rooted Taghaz, *Haloxylon ammodendron* Bunge, and a few shoots of a creeping sedge—*Cyperus conglomeratus* Rottb., (Tuzgh). Parts of this region, locally known as *Siah-Pat* (Black flats), form gravelly expanses along the flanks of hill ranges, and are more or less bare of vegetation, except for a few stunted bushes of thorny plants like Karkawag, *Fagonia arabica* L., and Bibi-butak, *Pycnocycla aucheriana* Decn. and 'Hashark' *Rhazya stricta* Decn. In alluvial flats occurring in parts of the Chagai-Kharan area, a more varied vegetation is observable. Bushes of large plants like Narrunk, *Salsola arbuscula*, Pall., Tusso, *Gaillonia aucheri*, Guill., Koh-tor, *Stocksia brahuica* Benth., Kharkh, *Calotropis procera* R.Br., Traht, *Haloxylon salicornicum* Bunge,

Kunar, *Zizyphus jujuba* Lamk., Hum, *Periplocaaphylla* Decne., and Phag, *Calligonum* sp., and smaller plants such as Karwan-kush, *Pteropyrum aucheri* J. et S., *Chrozophora tinctoria* (Popat, or Kapochisk), *Peganum harmala* L. (Ispantan), Balishtka, *Aerua javanica* Juss. and Barshonk, *Panicum turgidum* Forsk., are scattered all over the area. After the winter rains, various annuals come into existence of which Mughair, *Atriplex dimorphostegium* Kar. *et.* Kir., is very conspicuous by its abundance.

The coastal region

The greater part of this region is an area of winter rainfall, and it is only the extreme east, viz. the Lasbela area, that is subject to the influence of the summer monsoon.

Out of the coastal areas of Baluchistan, Iran and Eastern Arabia, the writer is familiar with the vegetational characteristics only of British Baluchistan. Maxwell-Darling [1937] recently examined the Muscat-Batina coast of the Gulf of Oman and the Pirate coast of the Persian Gulf and has given a short description of the common plants found there. As to Iran, exact information is not available, but since Predtechensky [1935, 2] who had thoroughly surveyed the Iranian territory during 1929-1931, has indicated that *reks* of the kind found in British Mekran are present in the Iran area, it may be presumed that the vegetation of the coasts of Iranian and British Mekran is for all practical purposes identical.

The flora of the coastal areas presents several differences as compared with that of the uplands. In conformity with a more southern latitude and a lower altitude, there is a change in its composition, there being a greater representation of tropical African and Arabian forms. The dominant trees of the area are the Kahur, *Prosopis spicigera* L., and the Khabbar, *Salvadora persica* L. and S. *oleoides* Decne. Chish, *Acacia arabica* Willd., and Chagirdh, *Acacia jacquemontii* Bth., and Kunar, *Zizyphus jujuba* Lamk, are also common where conditions are favourable. A few trees of *Tecomella undulata* G. Don. (Parpuk) may also be seen in places. In clay loams, the Leaflets Caper, *Capparis aphylla,* Roth, (Kaled) is abundant and reaches the stature of medium-sized trees. The Tamarisk, *Tamarix articulata* Vahl., (Bal. Siah-Gaz. *Br.* Kirri) is common along the beds of rivers.

In the interior of Mekran, as for instance in the Rakshan and Kolwa valleys, the general type of the flora is the same as in the Chagai-Kharan area, but with various additions: Hubb or Khip, *Leptadenia spartium* Wight., Lantu—*Taverniera nummularia* D.C., Delako, *Convolvulus spinosus* Burm., Guggar, *Commiphora pubescens* Engl., (found only in Lasbela area), Kulkushta, *Citrullus colocynthis* Schrad., Reghit, *Suaeda fruticosa* Forsk, Meshk, *Suaeda* sp., Simsur, *Suaeda salsa* Pall., Kunchitho, *Echinops tibeticus* Hg. T., and Shurdoo, *Zygophyllum coccineum* L. On the rocky beds of streams, the Dwarf Palm ,Peesh, *Nannorrhops ritchieana* Wendl., and the Oleander, Jaur, *Nerium odorum* Soland., are common. In sandy areas, bushes of Patto, *Calligonum polygonoides* L., and in moist situations, clumps of Leayyo, *Cressa cretica* L., may be met with.

Along the Mekran coast, sand-formations known as *reks* are, as already described, noticeable from Sonmiani on the east to Jiwani on the west, and according to Predtechensky, such *reks* exist also in the Iranian area. The vegetation on these *reks* is very peculiar. The whole area, the ridges as well as the hollows, is covered by low bushes of different kinds of plants, which usually assume a globose form by their being grazed down by herds of camels, goats and sheep. Most of the bushes are barely over two feet in height and on the average are not more than two feet in

diameter. After good rainfall, they tend to spread and coalesce with one another, especially when a thick growth of annuals has occurred in between them. Usually, however, the bushes are separated from one another by open spaces of sand one to three feet broad, in which locusts may frequently be found at rest on the ground, basking in the sun.

The dominant plant on the Mekran *reks* is what is known to the Baloch as Mazoung—*Sphaerocoma aucheri* Boiss. Numerically, it forms 50 to 60 per cent of the *rek* vegetation. In the *reks* of western Mekran, Marrand, *Heliotropium undulatum* Vahl., comes a close second, though as the food plant best liked by the locust it transcends all the other plants in importance. In the Lasbela *reks*, however, Marrand is scarce, its place being taken to some extent by Kharzan, *Sericostoma pauciflorum* Stocks, a plant only sparsely represented on the western *reks*. Other prominent components of the *rek* flora are: Tambo, *Crotalaria albida* Heyne, Shalwardir, *Asparagus curillus* Ham, Barshonk, *Panicum turgidum* Forsk., Jaduk, *Lycium europaeum* L. and Balibur, *Aerua javanica* Juss. (*tomentosa* Lamk.). Among the herbaceous plants found on the *reks*, especially after rainfall, are: Kullichk, *Cyperus arenarius* Retz., which sprouts up all over the sands from its underground stolons, Kuchak-pad, *Aizoon canariense* L., Litko or Harjangi, *Oldenlandia retrorsa* Boiss, Nalako or Maikh, *Neurada procumbens* Linn., Danichk, *Plantago ovata* Forsk., Sareng, *Tribulus terrestris* L., Halako, *Launea nudicaulis* Less., Puzzho-Marrand, *Arnebia hispidissima* D.C., Drajbagal, *Convolvulus pleuricollis* Boiss., Shanik-kush, *Lotus stocksii* Boiss., and various grasses, such as Gandil, *Dactyloctenium scindicum* Boiss., Sibar, *Cenchrus ciliaris* L. *Pennisetum dichotomum* Del., and *Eragrostis major* Hochst.

The depressions in the *rek* areas are generally of a clayish character and are usually more moist as the rain water percolating through the sand mounds gravitates into them. They support a fairly luxuriant vegetation of annuals in spring. Some of the plants found in such situations are: Pimaluk, *Asphodelus tenuifolius* Cav., Kahur-bahar, *Astragalus tribuloides* Del., Shimsh, *Trigonella corniculata* L., Guragpad, *Malva parviflora* L., Harigosh, *Emex spinosus*, Guval, *Trianthema pentandra* L., Leyyo, *Cressa cretica*, etc. In addition, bushes of Shimil, *Indigofera paucifolia* D.C., and Marrand may also occur there.

Wherever the soils are of a *kallar* or saltish character, bushes of xerophytes like Reghit, *Suaeda fruticosa* Forsk., Meshk, *Suaeda* sp., Jhawad, *Cornulaca monacantha* Del., Sorichk, *Atriplex crassifolia* Mey., Hashag, *Salsola foetida* Del., and Mund-kah, *Heleochloa dura* Boiss. develop and their clums, often dense, are scattered over the area.

It is interesting to find that many of these plants are included in the list of flora collected by Floyer [1882] in Qishm Island off Bunder Abbas in 1876 and identified in 1877 by Oliver and Moore of Kew Gardens, London. Floyer included *Sericostoma kotchyi* in his list of plants, and it is possible that the species of *Sericostoma* found at Pasni is *S. kotchyi*, as it presents certain obvious differences from *S. pauciflorum* (Kharzan), which is the common species in the Lasbela and Rajputana areas.

In the course of a survey of the Oman coastal areas in connection with locust breeding in Arabia, Maxwell-Darling [1937] has recorded the occurrence of the following plants among others: *Heliotropium undulatum*, *Cyperus arenarius*, *Leptadenia spartium*, *Prosopis spicigera*, *Arnebia hispidissima*, *Asphodelus tenuifolius*, *Salicornica fruticosa*, *Lycium persicum*, *Panicum turgidum*, *Pennisetum dichotomum*, *Salvadora persica*, *Calligonum comosum*, *Zygophyllum album*, *Trigonella hamosa*, etc. in the Oman area, which shows that the general facies of the flora of Eastern Arabia resembles that of the Mekran coast.

Even along the Aden Coast in South Arabia [Maxwell-Darling, 1937] and along the Jidda-Yemen Coast of the Red Sea [Hussein, 1938], and the Red Sea Coast of Sudan [Maxwell-Darling, 1936], the vegetation would appear to be more or less similar to that of the Mekran coastal area, most of the genera and even many of the species of plants being identical.

The region of north western India

According to Hooker and Thomson [1855], the flora of Sind is very largely composed of plants indigenous in Africa, while in the Punjab there is a large admixture of species of European and Oriental (Middle East) origin.

The vegetation of this extensive area roughly falls under three catagories of plant associations: (i) rocky or stony situations, (ii) loam or clay areas, and (iii) sand or sand-loam areas. Those of the first category are confined to the flanks of hill ranges, such as those of the Punjab and Sind foot hills, and are allied to the flora found on the adjoining hills. As the valley of the Indus, which is mostly alluvial loam, has been largely brought under cultivation, the character of the second type is to a great extent modified. Plant associations of the third category are most important from the view point of locust ecology, as sand or sand loam areas constitute the main habitat of the desert locust. As, however, even in typical desert, the soils of the hollows between sand-ridges, or of open country found in the midst of dunes, are generally of a clayey or clay-loam character, the plant associations of the second category are also represented in the desert.

Vegetation found in the desert areas. The Indian Desert covers a vast area of over 50,000 square miles of sandy soil. The region, however, is not a desert in the real sense of the term, for with an annual rainfall varying from 6 to 20 inches in its different parts, it is able to support a fairly dense bush vegetation throughout the year, while immediately after the fall of monsoon rains a rich growth of annuals, including grasses and legumes, transforms the whole country into an emerald pasture ground supporting innumerable cattle. When at its best, the general appearance of the Indian Desert is that of a rolling expanse of luxuriant vegetation, rather than of a sandy waste.

Trees. In the southern parts of the Desert, where there is more rainfall, vegetation is denser and trees are fairly common, especially Kumbat, *Acacia senegal* Willd., (*A. rupestris,* Stocks.), Jhal, *Salvadora oleoides* Decne. and Bavuri, *Acacia jacquemontii* Benth., which are found even on the dunes themselves. Usually trees are restricted to the lower portions of the dunes and to the hollows between ridges, and in these situations, the following trees or tall shrubs are also common: Khejri, *Prosopis spicigera* L., Gwangi, *Grewia betulaefolia* Juss., Kanketi, *Gymnosporia senegalensis* Loes, Liar, *Cordia rothii* R. & S., Bordi, *Zizyphus nummularia* W. & A., Rohida, *Tecomella undulata* G. Don., Arni, or Tankar, *Clerodendron phlomoides* L., Babul, *Acacia arabica* Willd., Kerdo, *Capparis aphylla* Roth., and Akdo, *Calotropis procera* R. Br.

While trees or large shrubs are not uncommon in the eastern parts of the desert, e.g. in Bikaner, they are almost absent in Jaisalmer, which is the least favoured as regards rainfall.

Shrubs. While most of the species occur all over the desert area, some of them are found to predominate in particular parts of the desert. The following are some of the common shrubs:

Phog, *Calligonum polygonoides* L., the dominant plant in many parts, Thuhar, *Euphorbia neriifolia* L. (found only in the southern areas) Guggar, *Commiphora pubescens* Engl. (mostly in the south), Siniya or chag, *Crotalaria burhia* Ham., Lana, *Holoxylom salicornicum* Bunge, (dominant in the drier areas, such as Bahawalpore and Jaisalmer), Murali (Pl. 6) L., Khip, *Leptadenia spartium* Wight., Kharsan. *Sericostoma pauciflorum* Stocks, (common only in the southern parts of the desert and fairly plentiful in parts of the cultivated areas of Jodhpur State), Murt, *Panicum turgidum* Forsk., (Pl. 9) found all over the desert, Siwan, *Erionurus hirsutus* Munro, covering large areas in parts of Jaisalmer and west Bikaner, Bishani, *Tephrosia hookeriana* W. & A., Meso, *T. procumbens* Ham., Gandhil, *Dactyloctenium scindicum* Boiss. Tumba or Tursan. *Citrullus colocynthis* Schrad. (a creeper common in most parts of the desert), Puida, *Andropogon schoenanthus* Spreng and *A. jwarancusa* Stapf., (growing in clumps in abundance in some parts). Baru, *Andropogon halepense* Biot., the wild Sorghum, grows in large clumps in parts of east Bikaner, while Sarkanda, *Erianthus griffithii* Hf., is seen in abundance in the Bahawalpur area.

Annuals. Among the annuals that spring up after rainfall, the Bharut (*Cenchrus biflorus*) (Pl. 8) is possibly the species most aggressively in evidence, not only because it is to be seen everywhere among the dunes, but also on account of its extremely spiny burrs, which stick to the clothes of people and the fleece of sheep and goats and cause extreme discomfort. The Lamp or Lamdo, *Aristida funiculata* Trin. *et* Rup. is another grass whose spear-like seeds pierce clothing and cause painful pricks. Vekkra or Bekkar, *Indigofera cordifolia* Heyne, and *I. linifolia* Retz. (Pl. 7) are extermely abundant in many parts of the desert, the ground being often densely carpeted with them. Bagra, *Gynandropsis gynandra* Merr. (*pentaphylla* D.C.), is also very common in some places. Among the rest are Trikandi, *Tribulus terrestris* L., Bhengri. *Blepharis sindica* Stocks, Rambus, *Arnebia hispidissima* D.C., Sanawri, *Boerhavia diffusa* L. Sareli, *Gisekia pharnacioides* L., Haran-chapri, *Farsetia jacquemontii* Hf. & T., Chidiyakhetar, *Mollugo cerviana* Seringe, Chappar-kanti. *Neurada procumbens* L., Lunak, *Zygophyllum simplex* L., Hanjo, *Melhania denhamii* R.B. and Phel, *Dipterygium glaucum* Dec., Satar, *Asparagus dumosus* Baker., has been found only in the extreme southern borders of the desert. *Heliotropium undulatum* is found all over the desert, but only in small quantities.

At the bottom of hollows between dunes and in the more moist localities in open areas the following plants may be found common: Dab, *Eragrostis cynosuroides* Beauv., Oyin, *Cressa cretica* L., Kanderi, *Alhagi camelorum* Fisch., Ghorawal, *Cassia obovata* Collad., Damaso, *Fagonia arabica* L., Mundheri, *Corchorus antichorus* L., Sata, *Trianthema pentandra* L., and clumps of *Panicum antidotale* Retz. (Gamol), and various other grasses.

On the whole, the plant communities found in the southern parts of the desert may be classified as 'Acacia—Desert grass savannah', while the rest of the Indian Desert area may be described as 'Desert shrub-Desert grass' vegetation.

In the course of a study of the solitary phase of the desert locust in the sand-dune country in Anglo-Egyptian Sudan, Maxwell-Darling has recorded the vegetation noted by him in N.E. Kordofan [1934] and in North Darfur [1936], and similarly Murat [1937] has given a detailed description in regard to the region of Lake Tchad in French Sudan.

Recently, Zolotarevsky and Murat [1938] have given detailed information on the vegetation found by them in the sand-dune areas of Mauretania in French Africa. A study of the flora listed by these workers shows that certain identical species found in the Sind-Rajputana desert also occur in all these areas, as for example, *Cenchrus biflorus (catharticus)*, *Panicum turgidum*, *Heliotropium undulatum*, *Aerua tomentosa*, *Gynandropsis pentaphylla*, *Melhania denhamii*, *Gisekia pharnacioides*, *Tribulus terrestris*, etc. and in addition many of the genera are identical. Moreover, these areas are all subject to summer rainfall, whereas the Red Sea and the Oman coastal areas, the vegetation of which is more or less similar to that of the Mekran Coast, fall within the zone of winter rains.

There is, thus, a certain striking resemblance between the Indo-Iranian habitat of the desert locust and the Africo-Arabian regions of habitat not only in the general physical conditions but also in the character of the vegetation. It is particularly interesting to observe that many of the wild food-plants found preferred by the locust in the Indian areas also occur in the African regions of habitat *Heliotropium undulatum*, *Aerua tomentosa* (=*javanica*) *Tribulus terrestris*, *Capparis aphylla* (*decidua*), *Chrozophora* sp., *Indigofera linifolia*, *Indigofera cordifolia*, *Tephrosia* spp., *Cenchrus catharticus* (=*biflorus*), *Panicum turgidum* and other species. *Crotalaria* spp., *Sericostoma* spp.

Studies in regard to the relative abundance and distribution of the various floral components in the different areas of habitat in Baluchistan, Sind and Rajputana were made in a few typical localities by the plant quadrat method. This will be dealt with at a later stage under Ecological Studies.

CHAPTER IV

SOME CHARACTERISTIC FAUNA

A STUDY of the fauna of locust habitats is important, as the life economy of the insect is likely to be affected by the activities of other animals inhabiting the area, either by their functioning as some of its predators or parasites or by their competing with it for food or living space. In certain cases, allied insects such as certain species of grasshoppers, which respond in a similar way to the climatic environment, may serve to give valuable clues in regard to the suitability of particular areas for locust breeding.

The fauna of the desert regions of India has received comparatively little attention from naturalists by reason of their general desolation and the lack of ordinary facilities for travelling. Owing to the importance of a sound knowledge of the fauna in an investigation of the locust habitats, efforts were made at the time of the commencement of the Locust Research Scheme in December, 1930 to secure the co-operation of the Zoological Survey of India in respect of undertaking a thorough survey of the fauna of Baluchistan and Rajputana. Unfortunately, however, the proposals did not meet with the sanction of the Government for reasons of financial stringency. However, various types of animals met with in the course of locust surveys were collected as far as possible by the staff, special attention being paid to forms likely to be of significance in studies of locust habitats.

The Indo-Iranian region of locust habitat is from the faunistic point of view, roughly divisible into two parts, (i) a western or Iranian, and (ii) an eastern or Indian. The western division would be composed of the uplands of Iran and Baluchistan and the coastal strips of Iranian and British Mekran and south-eastern Arabia, while the eastern would comprise the Indo-Gangetic Plains and the northern parts of Peninsular India.

According to Blanford [1907], nearly the whole Indian area is included within the zoo-geographical region known as the Oriental or the Indo-Malay, which comprises south-eastern Asia and the neighbouring islands. From considerations of the distribution of various genera and species of Vertebrates (chiefly Mammalia), Blanford, however, came to the conclusion that the north-western part of India comprised of the Punjab, Sind, Western Rajputana and Baluchistan should be removed from the Oriental or Indo-Malay region, and be regarded as the south-eastern extremity of the Eremian or Mediterranean subregion of the Palæarctic region [Blanford, 1901]. With reference to the geographical distribution of butterflies in the Indian area, Talbot [1939] gives in his introductory chapter a full statement of Evans' division of India into eight faunistic areas, which, with certain minor differences, coincide with Blanford's divisions in regard to Vertebrates. With reference to Evans' table, Talbot observes: 'Baluchistan (included in the area of North-Western India) is mainly Palæarctic and has affinites with Persia. Chitral is in the main a part of the Palæarctic. The western Himalayas (including Kashmir, Kangra, Nepal, Kumaon, etc.) are in parts Palæarctic and in parts Oriental'. Christophers [1921], in the course of a discussion of the geographical distribution of mosquitos in the Indian Empire, expressed the opinion that the Trans-Indus Area (consisting of the North-West Frontier Province, Baluchistan and part of Sind) was strikingly distinct by the possession of peculiar forms of Anopheles showing affinities with the fauna of Europe and Africa.

The distribution of Orthoptera in India may prove to be of interest though an authoritative pronouncement in the matter will not be possible till the studies of Indian Orthoptera, now in progress in London by Uvarov, are complete. Available data would, however, appear to indicate that the subdivisions of the Indian area, so far as the Acrididæ are concerned, will fall in line with those of Blanford [1901]. In the case of the subregion of north-west India (viz. Baluchistan, Sind, western Rajputana and the Punjab), the majority of the forms belong to general characteristic of the desert areas of western Asia and north Africa, so that the general facies of the Acridid fauna is definitely of a Palæarctic character.

There seems to be, thus, a certain unanimity of views as to the Palæarctic affinities of the fauna of the north-western part of India. Since a rational explanation of the facts in regard to the present distribution of animals in India can be obtained only by a study of the migration of faunas in the past as a result of geological and climatic changes, the Palæarctic character of the fauna of north-west India is obviously due to an infiltration of forms in recent geological times from the desert regions further west. Just as this region is climatically an area of transition between zones of winter and summer rainfall, and physically a belt of transition from the arid deserts of the west to the humid fertile tracts to the east, it is likewise a zone of faunal transition from the Palæarctic to the Oriental type.

[The author is indebted to Dr. Baini Prasad, (formerly) Director, Zoological Survey of India for supplying references on the subject of the affinities of the Indian fauna and for kindly going through the manuscript of this chapter].

Fauna of locust habitats

As already observed, the notes recorded here refer mostly to collections made, in the course of locust surveys of animals* likely to affect the life of the locust in its breeding areas. They do not pretend to be complete, nor do they purport to give a comprehensive view of the faunal complex of the desert. Fortunately, a great naturalist had done pioneer work in the desert areas of India, Baluchistan and Iran and has left fairly exhaustive and very valuable notes on the fauna observed by him. Blanford accompanied the Perso-Baluch Frontier Commission during the years 1870-72 and made extensive collections in Eastern Persia and Baluchistan, the results of which were published in Vol. II of '*Eastern Persia*', in 1876. In the winter of 1875-76, Blanford traversed the Sind-Rajputana desert from Umerkot to Barmer, thence to Jodhpur, Pokaran and Jaisalmer and thence across the sands of Shahgarh to Rohri, and in the course of this long trek, he made observations on the fauna and flora of the desert, which he recorded in a paper published in the *Journal of the Asiatic Society of Bengal* [1876].

Fauna of the Great Indian Desert. One of the great features of the desert area, next only to the general dominance of sand, is the scarcity of drinking water pools except in the rainy season, which acts as a serious handicap to the existence in the desert of the larger animals normally requiring a periodical drink of water. Among the mammals, the only carnivore seen in abundance is the desert fox (*Canis leucopus*) living in deep holes in the sides of the sand dunes. The wild cat, the hyaena and the wolf (*Canis pallipes*), may also be found occasionally in places. It is reported that the lion used to haunt parts of the desert about a century ago, but at the present day it is not to be seen outside the Gir forests of Kathiawar.

* A list of the animals collected at Pasni, along with their identifications, will be appended to the chapter on Ecological work.

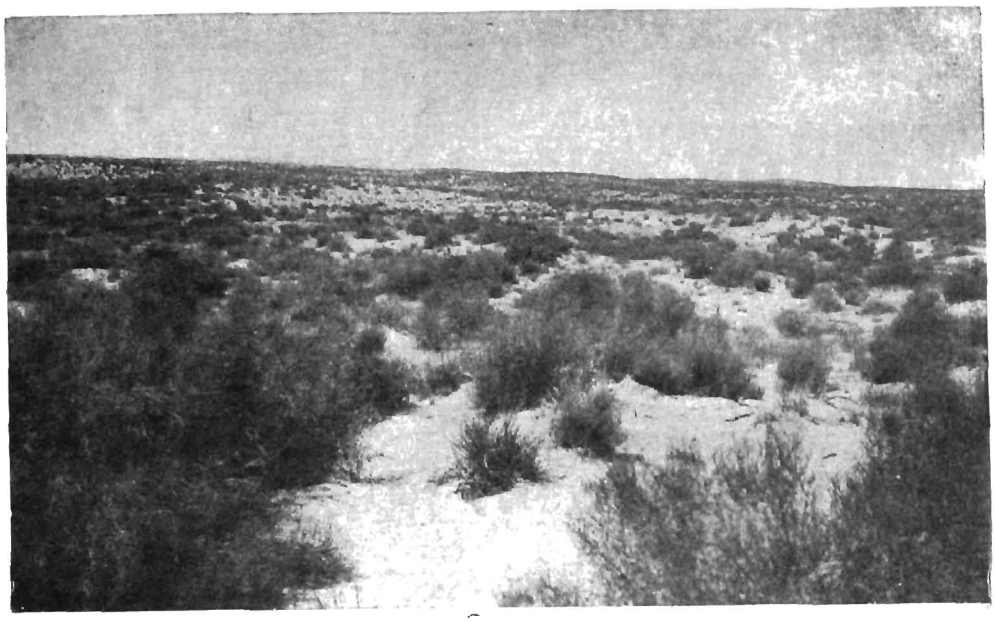


Plate 6.—*Desert to the north of Nokh*—Mostly covered with large bushes of Lana (*Haloxylon salicornicum*); fairly large clumps of Murt (*Panicum turgidum*) were also present—July, 1936.

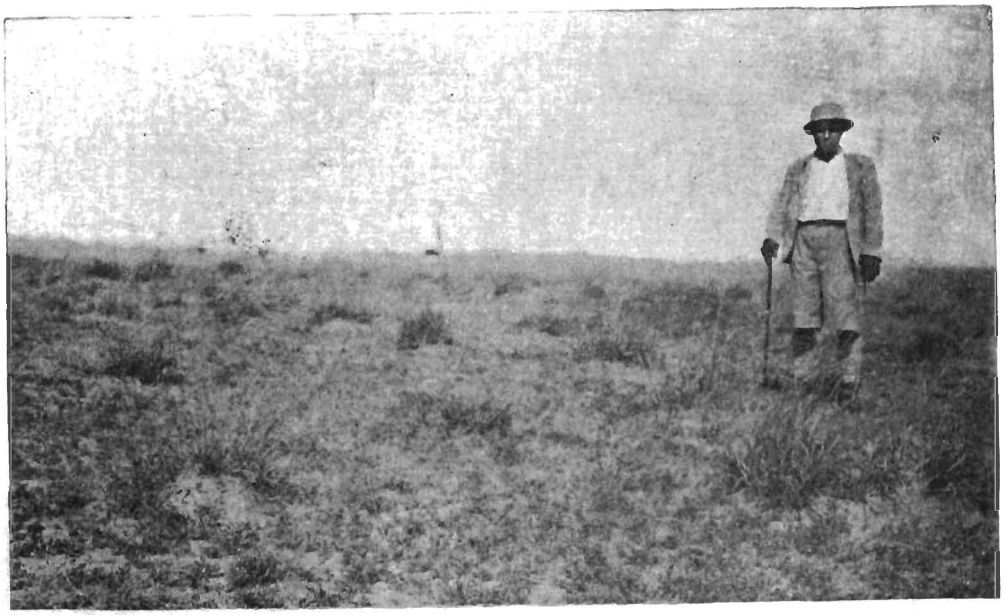


Plate 7.—*Open desert area near Girasar (Jaisalmer)* : Ground covered with recent growth (after June of Bekkar (*Indigofera cordifolia*) in foreground, as well as a few grass clumps of Siwan (*Elinurus*). Fairly good numbers of hoppers were seen here in July 1936.

Plate 8.—*Grass covered areas of the desert*—Near Sodakhor Jaisalmer; November, 1932; Grasses mostly Siwan (*Elionurus*) and Murt (*Panicum*). Several adults of *Schistocerca* and a small number of *Locusta* were found in these areas in November, 1932.

Plate 9.—*A rank growth of grass and annuals at Chachro*—Grass (mostly Bharut—*Cenchrus catharticus*) and Vishani (*Tephrosia*) and Wekra (*Indigofera cordifolia*) were found rapidly drying up at Chachro in September, 1935.

Among the Ungulates, the only representative is the Indian Gazelle (*Gazella bennetti*), found in fair numbers all over the desert. The most prominent among the smaller mammals is the Desert Gerbille (*Cheliones hurrianae*), whose burrows are conspicuously seen at the base of bushes almost everywhere. It is diurnal in habits and is commonly known in the Rajputana area as *Oondar*. The common Indian Jerboa-Rat, *Tatera indica*, known as *Rathod* in Marwar, is also present in many parts of the desert, but is not generally seen, as it is a nocturnal animal. It is known to have increased enormously in numbers in the past (as for instance, in 1893-94, in Marwar) so as to cause great destruction to crops. Hares are also seen in many places.

Among the birds, the following are commonly found in the desert: Raven (*Corvus corax ruficollis*), Falcon (*Falco jugger*), Buzzard (*Buteo vulpinus*), Scavenger Vulture (*Neophron percnopterus ginginianus*), Bee-Eater (*Merops orientalis orientalis*), King Crow (*Dicrurus macrocercus albirictus*), Grey Shrike (*Lanius excubitor lahtora*), the Common Babbler (*Argya caudata caudata*), the Desert Chat (*Oenanthe deserti atrogularis*), Black-headed Wagtail (*Motacilla feldegg feldegg*), Finch-Lark (*Pyrrhulauda frontalis affinis*), the Crested Lark (*Galerida cristata*), the Indian Roller (*Coracias bengalensis*), the Indian Sparrow (*Passer domesticus indicus*), the Bunting (*Emberiza huttoni*), the Rosy Pastor (*Pastor roseus*), the *Mynah* (*Acridotheres tristis*), the *Bulbul* (*Molpastes leucogenus leucotis*), the Brown Dove (*Streptopelia senegalensis cambayensis*), the Ring-Dove (*Streptopelia decaocto decaocto*) the Wild Pigeon (*Columba livia intermedia*), Sand-Grouse (*Pterocles exustus*), Grey Partridge (*Francolinus pondicerianus*), the Indian Bustard (*Eupoditis edwardsi*), etc. While a good many of the birds found in the desert are present throughout the year, others like Starlings, Buntings, Desert Chats and Wagtails, migrate north in spring for breeding outside India and return only at the end of summer. The Peafowl, (*Pavo cristatus*), is found semi wild in parts of the desert generally in the neighbourhood of human habitations.

Among the more conspicuous of the lizards, are the Desert Monitor (*Varanus griseus*), known as *Goh*, the common Sand Lizard (*Acanthodactylus cantoris cantoris*), the Bush Lizards (*Agama minor*) and (*Calotes versicolor*) and the Fat tailed Lizard (*Eublepharis macularius*), known as the *Gohira*. The Spiny tailed Lizard (*Uromastix hardwickii*) known as *Sanda*, is herbivorous in habits and lives in holes excavated by itself in hard clayey ground in valleys between sand ridges. In the Baluchistan area, it goes by the name of *Patti-Mahi* or the 'Fish of the plains'. *Ophiomorus tridactylus* is a common snake-like Scinck, whose vermiform tracks are seen almost everywhere on the surface of loose sand on the dunes.

Snakes are not uncommon, and among the nonpoisonous kinds are species of *Zamenis* and *Psammophis* and the Sand Snake, *Eryx johnii*. Among the poisonous snakes are the Aoughscaled Viper, *Echis carinata*, familiar to desert residents as *Pharad* and known in Baluchistan as *Garr;* the Sind Krait, *Bungarus sindanus*, the dreaded *Piwana* of the desert; and the Cobra, *Naja naja*. All of them hibernate in winter.

Among the Invertebrates, the Class Insecta forms the dominant group in the desert as elsewhere. The most conspicuous among insects in the sandy areas is the omnipresent *Scarabaeus sacer*, the Egyptian Dung Roller.

Ground beetles, such as *Trox desertorum* and *Pimelia inexpectata* are also common on sand dunes. Various grasshoppers are found in greater or smaller numbers all over the area, the following being the common genera: *Sphingonotus, Acrida, Acridella, Aeolopus, Helioscirtus, Chloebora, Acrotylus, Thisoecetrus, Caloptenopsis, Euprepocnemis, Anacridium, Poecilocerus, Catantops, Oedipoda, Platypterna, Locusta, Patanga,* etc. Among the Tettigoniidae, the peculiar burrowing form, *Schizodactylus monstruosus,* has been found in many parts of the desert, though on account of its nocturnal habits, its presence is not generally noticed. Mantids are met with in small numbers among the vegetation all over the desert, the commoner genera being *Rivetina, Blepharopsis, Empusa, Iris,* etc. Various species of Neuroptera (mainly Myrmeleonids), Diptera, Hymenoptera, and Hemiptera are met with in the desert, though not in abundance. A few scale insects (Coccidae) have been collected in the desert on various plants, of which the striking form, *Naiacoccus serpentinus* Green, on Tamarisk, with its waxy egg sacs curled into a snakelike shape, and the waxy white Mealy Scale, *Pulvinaria cypriotis* Green on *Haloxylon salicornicum,* may be specially mentioned. Among the Lepidoptera, various butterflies are found during the rains, while the day-flying moth *Utetheisa pulchella,* which breeds on *Crotalaria burhia* and *Heliotropium* spp., is often seen in abundance. Though insect life is comparatively scarce in the desert during the dry season, there is an outburst of activity soon after the fall of rains, and the multitude of insects of all kinds that crowd together on the table lamp at night after the break of the monsoon and make any kind of desk work impossible, controverts all preconceived ideas about insect life in deserts.

Among the Arachnids, the most striking form is the swift footed *Galeodes,* individuals of which, often of fairly big size, may be found invading camps and houses, much to the disgust of the occupants. Ticks are extremely abundant and seriously infest the cattle. The Velvet Mite, *Trombidium grandissimum,* is found emerging in large numbers on the ground after the first heavy rain of the monsoon. Centipedes (*Scolopendra morsitans*) are fairly plentiful in many parts of the desert. Various spiders and a few scorpions may also be noticed. Castings of a large species of earthworm have also been found in parts of the desert after rainfall.

Lastly, although unconnected with locust ecology, the small desert snail, *Zootecus insularis,* Ehr., deserves mention as almost the sole representative of the class Mollusca in desert areas. The shells are small, white, and pupiform. In fact, they present a striking likeness to the pupae of small moths. The shells are found in abundance in many places, as for instance in the Lasbela area, around Karachi, and in the southern parts of the desert (Thar, Mallani and South Marwar) and in Kathiawar. They have also been collected in small numbers in Kachhi and the central parts of the desert; at Pasni, however, they are very rare. In general, only empty shells are seen, live specimens being observable only after the break of the rains, at the base of vegetation. Probably they aestivate in the soil during the rest of the year. This form is probably co-eval with the development of the desert, as the shells have been found imbedded in the dunes at all depths. According to Tryon and Pilsbury [1906] the form is distributed from the Cape Verde Is., eastwards across Africa and Arabia, to India and Burma.

Fauna of the Iranian region. As locust survey work had been restricted to the southern parts of Baluchistan at a very early stage of the investigation, there was not much scope for studying the fauna of the

upland areas of Baluchistan, but from the scanty observations made during the first year of the work and from the information available in the District Gazetteers of the province, it is evident that the fauna is allied to that of Iran and Central Asia.

As to the Coastal areas of Baluchistan, Iran and south-eastern Arabia, information has been collected only for the areas belonging to British Baluchistan, but there is apparently not much reason to think that the fauna of Iranian Baluchistan would differ very much from that of the contiguous British area. Blanford [1876, 2] has reported on the Vertebrate fauna of Eastern Persia and found a certain degree of similarity between the fauna of Eastern Persia and north-west India.

Among the Lizards, the following species have been found on the coastal *reks* of Mekran: *Stenodactylus orientalis* (?)—a Desert Gecko, *Acanthodactylus cantoris*—a Sand Lizard, *Agama agilis, Eumeces schneideri, Chalcides ocellatus, Ophiomorus brevipes*, Blanford, (known as *Reg-mahi* or Sand-fish) (the last three being Scincs) and *Varanus griseus*. *Eremias brevirostris* has been collected in the interior of Mekran.

Bufo viridis, Rana hexadactyla and *Rana cyanophlyctis* are among the Amphibians observed in Mekran. Among the snakes collected in the Baluchistan areas are *Zamenis karelini, Zamenis diadema, Psammophis leithii, Tropidonotus subminiatus, Dipsadomorphus trigonatus* and *Echis carinata* (*Garr* in Balochi). Of these the last species alone is poisonous.

Among the Arachnids are *Buthus macmahoni* and *Butheolus melanurus* —(two of the scorpions found in Mekran), and species of *Galeodes* and *Galeodellus*, (*Solifugid* spiders common in the desert).

Among insects, the following have been found common: Tenebrionidae; species of *Adesmia, Spyrathus, Tentyria, Oxycara* and *Pimelia;* Copridae: *Heliocopris gigas, Gymnopleurus, Scarabaeus, Onthophagus* spp.; Nemopteridae: *Croce filipennis*, and *Halter mutans;* various Myrmeleonidae; Gryllidae: *Gryllus domesticus, Liogryllus bimaculatus;* Tettigoniidae: *Schizodactylus monstruosus;* Acrididae; most of the genera noted in the Indian Desert are also found in the Mekran areas, and in addition, the following are also observable: *Dericorys, Thisoecetrus, Eremocharis, Tmethis, Scintherista, Calliptamus* etc. Among the Mantids, the short-winged form *Eremiaphila braueri* is common in stony desert areas.

Fauna of African areas. While perusing reports of Locust research work, notes were taken on the fauna recorded from parts of Asia and Africa subject to locust invasions and a comparison of the faunal components shows a remarkable identity of the genera, and even of species in some cases. There is a close resemblance between the Reptilian fauna of Mekran and Tunisia [Mosauer, 1934], and Egypt (Ballard, Mistikawy and El Zoheiry, 1932), and of the Bird Fauna of Mekran and Egypt [Ballard *et al.*, 1932]. In regard to grasshoppers, many of the genera and some of the species are common between Mekran and Egypt, [Uvarov, 1924] and a similar correspondence between forms found in Sudan [Maxwell-Darling, 1934] and the Lake Tchad Region [Golding, 1934], and those found in the Iranian Desert area and in Mekran is observable. In the case of the genus *Hieroglyphus*, in which the life cycle is adapted to summer rain conditions, it is remarkable that it should be found in India and in parts of Mekran subject to monsoon influence, and, again, in the Lake Tchad and Senegal areas in Tropical Africa, also regions of summer rainfall.

Effect of the faunal complex on the locust. In view of the wide spaces in which the life of the Desert Locust is cast, and of the general abundance of plant food when favourable rainfall occurs, there is little chance of a risk of competition either in regard to plant-food or living space, especially in its solitary phase. Even in its gregaria phase, there is a greater chance of competition for food between individual bands of hoppers than between locusts and other animals—except perhaps in the case of herds of livestock.

The impact of the animal environment on the Locust would appear to be felt mainly in the role of predator or parasite. As to parasite enemies, very few have been noted on the solitaria locust, with the exception of the nymphs of two Acarids. In the case of the gregaria type, two species of Calliphorids have been reared out from adult locusts in Baluchistan. Of predators, there is legion. All the carnivorous mammals feed on locusts, wherever they meet with them. The birds, however, appear to be their most common foes. Starlings, Bee-eaters, King-crows, Babblers, Shrikes, Rollers, Harriers, Hawks, Storks, Wagtails, Desert Chats, Larks, Vultures, Crows and a whole host of them attack the locust, whenever it is found in numbers. The solitary phase locust, however, generally escapes detection so long as it is immobile and does not take wing. Many of the lizards, especially the larger species, are able to capture adult locusts while the smaller ones usually attack the hoppers. *Acanthodactylus* and *Eumeces* were found on dissection to have green hoppers of the solitary phase among their stomach-contents at Pasni. In one instance an adult locust was dissected out of the stomach of a Viper, *Echis carinata.* Frogs, toads, scorpions, spiders and centipedes are also known to attack hoppers.

It is, however, evident that the action of natural enemies, although quite considerable at times, is not by any means as powerful as that of adverse climatic conditions in bringing about the decline of a locust out-break.

SECTION III. STUDIES ON THE DISTRIBUTION OF THE SOLITARIA PHASE DURING 1931-38

CHAPTER I

INTRODUCTORY: SURVEY METHODS

IN 1930, there was no definite information available as to the source of the periodical infestations to which India is found subject. Although the generally accepted view was that the initial swarms reached India from a western direction, there was no positive evidence to indicate either that they had their origin from outbreak centres situated within Baluchistan, or that they merely formed a link in the chain of secondary breeding grounds connecting India with Arabia and Africa. From the point of view of the prevention and control of future locust invasions, it was obviously of the utmost importance to secure a decisive answer to this question. If it could be proved that the outbreak areas were within Indian limits, there was a fair chance that appropriate measures backed by Indian legislative support could be devised to nip future outbreaks in the bud, whereas in case their origin should be wholly or partly outside India, their prevention or control would be a matter requiring action on an international scale.

Preliminary Locust Surveys, 1931—33. It was with the aim of detecting the presence of permanent or semi-permanent breeding grounds, if any, within Indian territory, that a special locust survey staff was appointed early in 1931 and stationed in Baluchistan (with Quetta as headquarters) in the first instance, as the province where such breeding grounds were most likely to be found. In the course of the year 1931, the survey staff examined the areas of Chagai, Lasbela, Mekran and Kharan between February and May, and were able to locate fair numbers of locusts and hoppers, presumably, of the solitary phase in the coastal areas of Mekran. By April-May 1931, however, locust swarms were reported from various parts of Upper Baluchistan, and as this introduced an undesirable element of complication, further survey work was suspended till they began to disappear from Baluchistan by September. In the meantime, the staff was engaged in experiments on locust control in the affected areas of Upper Baluchistan, and also in making observations on the movements of swarms, (especially in Quetta-Pishin, Loralai and Sibi). In September, a survey party led by the writer traversed the desert areas of Kharan, beginning its itinerary on 21 September from the railhead at Ahmedwal in Chagai and terminating it at Panjgur on 4 October, passing *via* Patkin, Nauroz-Kalat, Kharan-Kalat and Washuk. The Mekran and Lasbela coastal areas were revisited in September-October by an Assistant who confirmed the existence there of adult locusts of the solitary type first detected in May.

During the following years, similar preliminary surveys were carried out in the rest of the desert or semi desert areas of North-West India, *viz.* Kachhi, western Sind, Lasbela, eastern Sind, Jhalawan, Kech and Kolwa. Loralai, the Dera Ghazi Khan and Bahawalpore areas of the Punjab, the Thar area of Sind and various areas of the Rajputana desert, such as parts of Bikaner, Jaisalmer and Marwar (including Mallani). Surveys of Sirohi, Palanpur, Radhanpur and Cutch States carried out in the early months of 1933 completed the programme of tours designed for obtaining data on the distribution of the solitary phase locust within Indian limits. It should be mentioned here that during the years 1932 and 1933 survey work was greatly facilitated by the provision of a one-and-a-half ton Ford motor van, as it not only served to take the survey party with

all their equipment to many comparatively inaccessible places, far removed from the railway track, but also helped to effect considerable economies in the cost of survey work. In all those areas, however, where the motor van could not be used, as in the interior of sandy deserts, journeys were performed on camels.

These extensive surveys amply served the purpose for which they were planned. The results obtained gave a general idea of the distribution of the solitaria locust population in the Indian area. With the disappearance of locust swarms by the end of 1931, few locusts were to be seen in most parts of Upper Baluchistan and in the cultivated areas of Sind and the Punjab. On the other hand, individuals of the non-gregarious type of the Desert Locust were found occurring, at times, in concentrations of varying strength, but more often, scattered sparsely over sandy areas of the Mekran Coast and over various parts of the Sind Rajputana desert. It was, however, obvious that the records of observations on locusts made in the course of these surveys had reference only to the conditions prevailing at the time, and that further surveys, repeated at different parts of the year, would be needed before any inferences in regard to their functioning as permanent reservations of the locust could be made. Moreover, in the course of survey work, a fluctuation of locust population was actually found to have occurred in certain instances. In April-May, 1932 no locusts were noticed in the Sonmiani area of Lasbela State at the time of the visit of the survey party, but by August-September 1932 large numbers of locusts, both hoppers and adults, were found there in the wake of good monsoon rainfall in July. On the other hand, a fairly heavy concentration of solitary type locusts was detected at the end of March 1932 at Angare-Gadap about 15 miles north of Karachi, after a sharp fall of rain, and light breeding was observed there during April-May, though very few locusts have ever been found in that locality in subsequent years.

Intensive Regional Surveys, 1933—38. In the light of the experience thus gathered, it became evident that the type of surveys needed at this stage should be such as could lead to information on the effect of seasonal changes on the behaviour and activities of the non-gregarious type of locust. Consequently, survey tours of the extensive type were given up, and with effect from June 1933, survey work was restricted to the areas where solitary type locusts had been found, such as parts of Mekran, Lasbela and the Sind-Rajputana Desert, inclusive of Jaipur, Bahawalpur and Khairpur States. Since 1937, owing to the detection of very intensive breeding in Kachhi and in the contiguous hill valleys of Baluchistan, such as Bolan and Harnai, these areas were also subjected to regular periodical surveys. The areas of habitat of the locust were divided into circles and sub-circles of convenient size which were placed under the charge of staff of the grade of Assistants and Fieldmen respectively for purposes of survey work. With the experience gained after a year of intensive surveys, a regular round of visits was arranged for each sub-circle in such a way that every area was visited once a month wherever possible, or at least once in two or three months in the case of particularly large or difficult areas.

During the years 1933 and 1934, some of the areas could not, on account of the inadequacy of the staff sanctioned, be visited frequently enough to enable a complete picture of the happenings in the locust habitat being obtained, but from 1935, with the gradual expansion of the staff and the consequent completeness of the information obtainable it has been possible to follow locust developments in the whole of the Indian region fairly closely, so as to get a correct perspective.

The following was the organization that was existent during the year 1938 for watching locust developments in the Indian areas:—

I. MEKRAN CIRCLE: Supervised by the Mekran Survey Assistant stationed at Pasni.

(i) Gwadar Sub-circle: The Gwadar-Pishukan-Jiwani area: under the Gwadar Fieldman.

(ii) Turbat Sub-circle: composed of the areas of Kech, Buleda and Kolwa: under the Turbat Fieldman.

(iii) Panjgur Sub-circle: composed of the areas of Panjgur, Nagi-i-Kalat and Gar-Parom: under the Panjgur Fieldman.

(iv) Kulanch-Dasht Sub-circle: composed of Kulanch and Dasht: under a Fieldman stationed at Pasni.

(v) Ormara Sub-circle: composed of the Ormara-Gazdan-Rumra areas: under a Fieldman stationed at Pasni.

II. LASBELA CIRCLE: Supervised by the Ambagh Assistant.

(i) Hingol Sub-circle: composed of the areas of Nakhetri, Khandewari, Pohr and Hingol: under a Fieldman stationed at Ambagh.

(ii) Hinidan Sub-circle: composed of the areas of Shahbilawal, Hinidan, Kila and Hab-Chowki: under a Fieldman stationed at Ambagh.

(iii) Bela Sub-circle: composed of the areas in the interior including Liari, Sheh Lakhra and Bela: under one of the Ambagh Fieldman.

III. THAR-MALLANI CIRCLE: Supervised by the Barmer Survey Assistant.

(i) Thar Sub-circle: composed of the areas of Thar (Sind) and south Jaisalmer under the Chachro Fieldman.

(ii) Mallani Sub-circle: composed of Mallani, South Marwar and Kathiawar areas: under the Barmer Fieldman.

IV. BIKANER-JAISALMER CIRCLE: Also supervised by the Barmer Assistant, but formerly under a separate Survey Assistant stationed at Khanpur.

(i) Jaisalmer Sub-circle: composed of the areas of north Jaisalmer and Bahawalpore: under the Nokh Fieldman.

(ii) Bikaner Sub-circle: composed of the areas of Bikaner, west Jaipur and S. E. Punjab: under the Fieldman at Sardarshahr.

V. KHAIRPUR-KACHHI CIRCLE: Supervised by the Assistant Entomologist, Karachi.

(i) Kachhi Sub-circle: composed of western Sind, Kachhi and Upper Baluchistan: under the Fieldman at Sukkur.

(ii) Khairpur-Dera Ghazikhan Sub-circle: composed of Khairpur and Dera Ghazi Khan areas: also under the Sukkur Fieldman.

Concentrated Local Surveys 1934—38. Though a system of regional surveys mentioned above has been of great value in giving a definite indication of the locust situation in the area concerned in different parts of the year, yet, owing to the circumstance that the surveys

were spread over a large area, they could not give a continuous picture of the happenings at particular places. In the course of survey work, the data collected indicated not only that there was a fluctuation in the density of locust population at particular localities but also that seasonal movements of the population were probably occurring. In order to obtain definite proof of such a phenomenon, intensive survey work was carried out, from 1934 onwards, at selected places with the object of keeping them under continuous observation during a series of years.

In January 1932, a locust research station was opened at Pasni in the Mekran Coastal area with the object of carrying out ecological studies of the *solitaria* locust in one of its natural areas of habitat. Another similar station though on a smaller scale was opened in June 1933 at Ambagh in the Lasbela State for making observations in an area subject to summer rainfall, Pasni being a centre for winter rainfall areas. In 1934, two desert outposts were established at Chachro in Sind (Pl. 11) and at Sardarshahr in Bikaner (Pl. 10), and in the following year two more were opened one at Nokh in Jaisalmer and the other at Barmer in south Marwar, for the purpose of studying the activities of the locust under desert conditions and their reactions to seasonal changes. Of these, however, the Barmer Outpost was abolished in 1936. All these stations were utilized for carrying out regular local surveys, so as to have a continuous record of locust population density throughout the year. In the course of five years, valuable results have been obtained, affording fairly clear evidence in regard to the occurrence of a migration of individuals.

In addition, the fieldmen stationed at Gwadar, Turbat and Panjgur were also instructed to make local surveys around their stations whenever they were not engaged in touring.

Thus, continuous records regarding locust activities have been obtained at the following stations:—

1. Pasni: as a centre for the western reks, in the region of winter rainfall (records from 1932),
2. Ambagh: as a centre for the eastern areas of the Mekran coast, subject to summer rainfall (from 1933),
3. Chachro: as a centre for the south-western parts of the Indian Desert (from 1934),
4. Sardarshahr: as a centre for the north-eastern parts of the Desert (from 1934), and
5. Nokh: as a centre for the central parts of the Desert (from 1935).

Methods of field survey and of estimation of locust populations

One of the main objects of carrying out locust surveys was that of getting an estimate of the density of locust populations at the time of surveys. Considering the diversity of the environment of the locust, especially in regard to the character of the vegetation, it is a very difficult proposition to make even an approximate estimate. An absolutely correct calculation would be impossible unless the area is combed out thoroughly at considerable cost and trouble, and under ordinary circumstances, it is neither possible nor desirable to aim at such costly precision.

In regard to methods of field surveys the Third International Locust Conference held at London in September 1934 considered that in each country entomologists engaged in field work should themselves choose

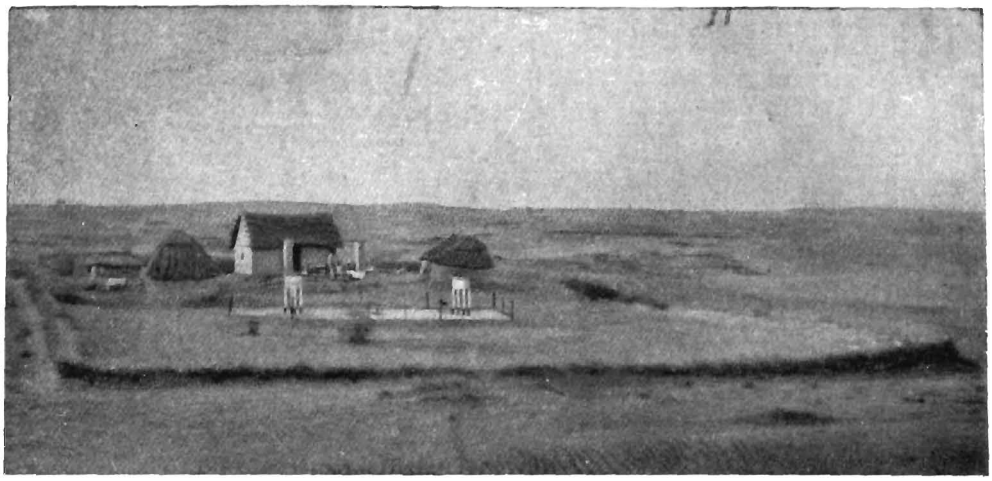


Plate 10.—*Sardarshahr locust outpost*—Located on the top of a bare dune. The compound fenced with thorns contains the meteorological plot, as well as a small laboratory and a few huts for the accommodation of the workers.

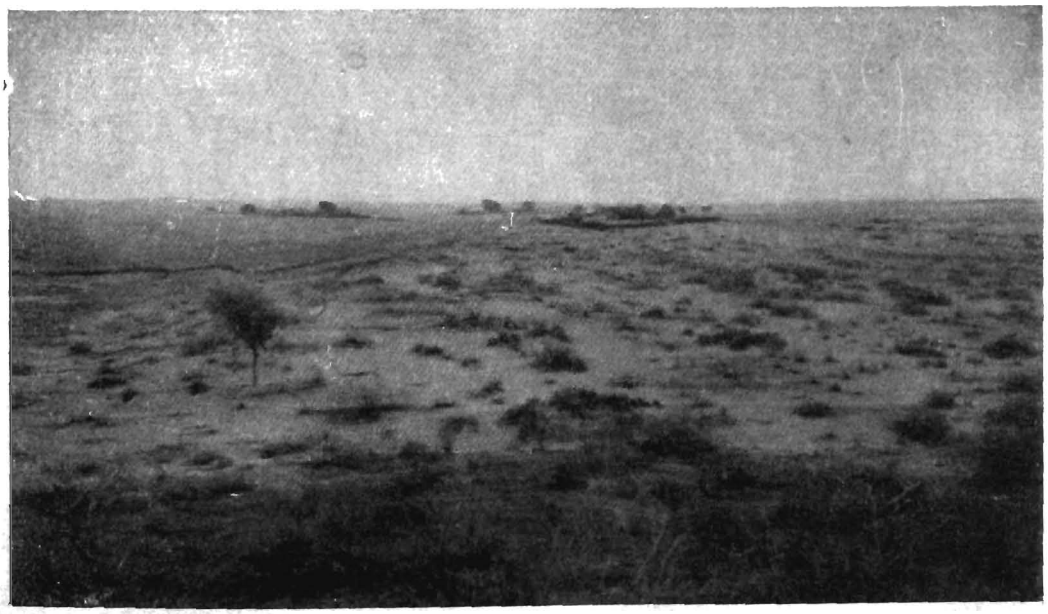


Plate 11.—*Chachro locust outpost* on top of a sand-mound; also showing the desert country roundabout. The larger bushes are mostly Calligonum, Calotropis and Capparis (February 1937).

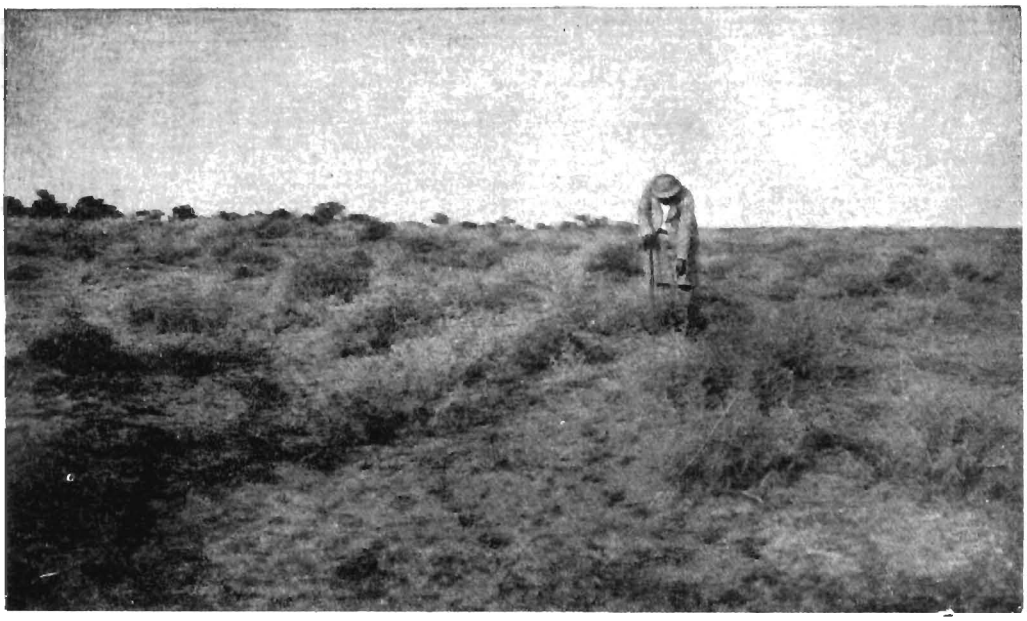


Plate 12.—*Desert area between Pugal and Rojri* : August, 1937 : Booh plants (*Aerua*) being tapped gently with a stick to note the number of hoppers jumping out of the bushes.

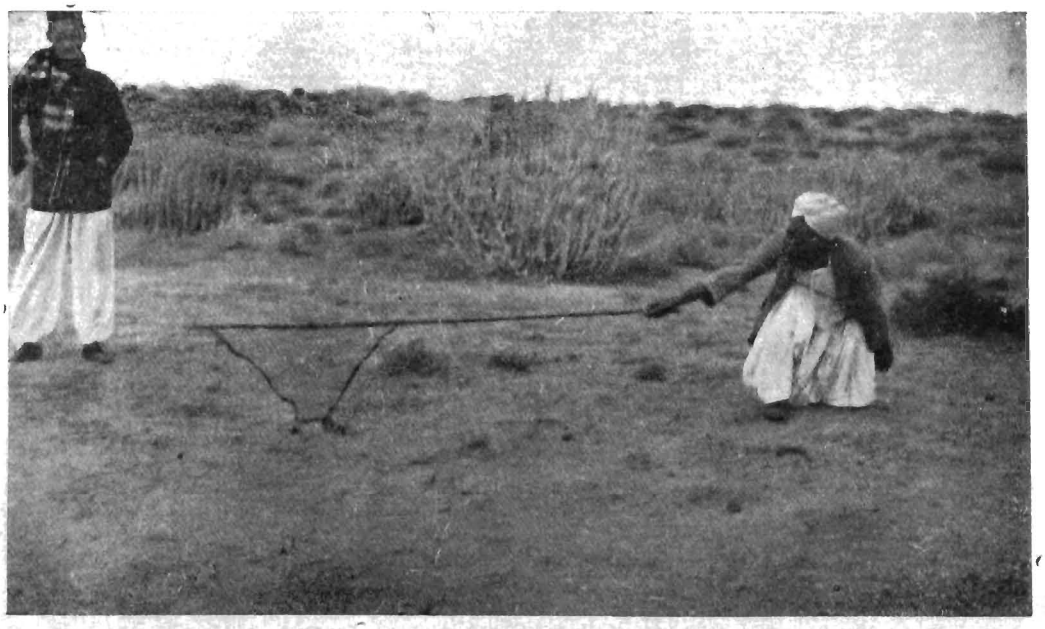


Plate 13.—*A method of catching solitary locusts* : A piece of old fishing net is attached to the end of a stick as in photograph. The surveyor keeps as far as possbile from the locust and slowly brings piece of netting nearer and nearer until it hangs vertically over the insect at a distance of about 4 to 6 inches, when it is suddenly dropped flat on the locust. The latter is entangled in the netting and is captured before it can get free.

the methods which in their opinion were the most likely to secure the objects to which the research is directed. It, however, stressed the importance of uniformity in estimating locust populations which was desirable as between different territories and was essential within each territory. The ideal method of estimating population was, in the opinion of the Conference, by the counting of numbers per unit area. Where in any particular territory the density of vegetation or other causes prevent this method from being sufficiently accurate, countings should be by numbers seen or caught per unit of time [*Proc.* 1934].

One of the recommendations of the Conference was that in making population studies of locusts it may in some circumstances be of value to include other species of insects or even other animals. Golding [1934] included all Acrididae in his estimation of locust population. Sample collections were made by ten men in line who kept at constant distances from their neighbours and proceeded slowly for 15 minutes through each habitat. Several collections were made in each habitat every month and the mean of the catches was calculated for the various stations. In this method the time unit was employed in estimating the population.

Maxwell-Darling [1934] too included other Acrididae in estimating locust population. He pegged out areas in several localities, and counted all the individuals of each species seen while walking up and down. The time of optimum temperatures when the maximum number of each species was seen was ascertained and the number recorded at the optimum temperatures was taken to represent the population of the area, from which the relative density was worked out.

Smit [1939] employed three methods in estimating the adult populations of the Brown Locust in outbreak centres in South Africa.

(1) *The Combing Method.* To determine the population of adults per plot of 2,500 sq. yards (100 yd. × 25 yd.), the observer walked along a series of parallel lines, 2½ yards apart. To comb such a plot, he had to walk along 40 different parallel lines, *i.e.* a total of 1,000 yards. The reliability of this method depends on whether the insect will move sufficiently to attract attention when the observer passes it at a maximum distance of 4 feet, which it never fails to do under a clear sky and favourable temperatures (70°F. and higher). This method appears to be fairly reliable under favourable weather conditions, and it takes one observer approximately one hour per acre to determine the adult population by combing.

(2) *The Distance Method.* The number of locusts observed by the surveyor was counted as he walked along a line of known length. The method is reported to have given very satisfactory results and was found useful for random counts.

(3) *The Time Method.* The observer paced through the field at a uniform speed of approximately three miles an hour and recorded the number of locusts observed in a known interval of time. The last method was the one followed by Faure [1934] in estimating the locust population in S. W. Africa at the time of the swarming of *Schistocerca* in May 1934, the number of locusts that can be counted by one man walking at about three miles per hour being used to express the relative density of population in terms of their number per man-hour.

In the course of surveys carried out in the Indian areas, notes in regard to the finds of other Acridids, especially the larger species, such as *Locusta migratoria, Patanga succincta, Anacridium aegyptium,*

Cyrtacanthacris tatarica, and species of *Caloptenopsis, Acrida, Catantops, Thisoecetrus,* etc. were also recorded, but no attempts have ever been made to take into account the existence of other species in estimating the locust population, for the reason that there was little evidence to show that there was any ecological connection between the Desert Locust and various local grass-hoppers, except perhaps in a simultaneous breeding activity exhibited after rainfall. In this connection, it is interesting to find that Smit had a similar experience in South Africa [Smit, 1939]. He writes: 'No special attention was paid to the population densities or the distribution of the grasshoppers, since there has been no evidence of any close association, either positive or negative, between any species of grasshoppers and *Locustana pardalina.*'

Method adopted for estimating Population Density. In the earlier years of the present scheme, no serious attempts were made in regard to the working out of a method of estimating the density of locust population noted during surveys. In all cases, however, the number of locusts or hoppers observed or collected was noted down, as well as fairly detailed particulars of the areas examined. In certain cases, the surveyors gave rough estimates of the population density according to their lights, which, however, are apparently of little value, as the figures are not exactly comparable.

It was not till January 1935, when the Locust Advisory Committee of the Imperial Council of Agricultural Research met and discussed the Annual Progress Report of the Locust Research Scheme for the year 1934, in conjunction with the recommendations on the subject of field surveys by the Third International Locust Conference of 1934 and made definite suggestions in the matter, that a general formula for working out the population density of locusts under Indian conditions was evolved. This formula has been in use, with slight modifications, since 1935, and has, on the whole, proved quite satisfactory.

In the course of the surveys, it was a matter of common observation that the solitary phase type individual is usually to be met with resting on the ground in open patches between bushes. It, generally, loves to sit basking in the sun, while the sand surface temperatures range roughly between 80° and 100°F. (25° and 37°C.), but when the soil temperature rises above 100°F. (37°C.), it either changes its place by flight or crawls into shade, usually under a bush, seeking shelter from the sun's rays. On the other hand, when the soil surface temperature falls below 80°F. (about 25°C.), the locust is not very active, it prefers to sit basking in the sun as long as possible and ultimately retires for the night to the base of a bush. The locust is most active between the range of 80° and 100°F. (surface soil temperature), and it is only then that the best results can be obtained in respect of survey work. During summer months, the optimum time for surveys may be taken to be between 8 A.M. and 11 A.M. and between 4 P.M. and 7 P.M., while in the winter months the best period would be between 10 A.M. and 3 P.M.

When locusts are most active, they are very sensitive to the approach of men and rise abruptly from the ground or bush and fly out. Curiously enough, they do not seem to mind the approach of camels or cattle unless they come too near them. When, however, an observer walks along waving a stick, alternately on the right and left side, as he marches forward, one may be sure that very few locust individuals will remain undetected. From practical experience it has been found that, with a stick in his hand, a man can count upon his being able to start locusts, as he walks along up to a limit of 10 to 12 feet on either side. A distance of 11

feet has, however, been fixed rather arbitrarily, as that number is convenient for purposes of calculating fractions of a mile. The distance travelled by an observer during a survey can be determined either by means of a pedometer, or approximately in other ways. Supposing for example, a man had walked three miles during his survey and had found 10 locusts, the area covered by him might be computed in square miles by multiplying 3 miles (the length) by 22 feet or 22/5280th of a mile (the breadth—which is the range of his influence on either side). Since by calculation it is seen that within this area of $3 \times 22/5{,}280$ or 1/80 sq. mile 10 locusts were found, the approximate population density is worked out to be about 800 locusts per sq. mile. Taking another case, where a party of five surveyors had been marching along at a distance of about 20 to 30 feet apart from one another and had met with 20 locusts in all during a survey of three miles, the results might be worked out by computing the total area surveyed by all the five men, *viz.* $5 \times 22/5280 \times 3$ sq. miles, or 1/16 sq. mile and calculating therefrom the density of population, which is found to be 16×20 or 320 locusts per square mile.

The general formula would thus be as follows:

$$P = \frac{L}{M \times 22/5280 \times D} \qquad \frac{L \times 5280}{M \times 22 \times D}$$

'P' standing for Population Density, 'M' for number of Observers, 'D' for Distance in miles, and 'L' for number of Locusts found.

If surveys are conducted during the optimum periods in respect of locust activity, this formula will be found to give a fairly correct estimate of the population density. At any rate, when the same method of calculation is followed all over the Indian area, the figures obtained would be comparable in all respects.

This method is approached most nearly by Faure's man-hour method, and his estimate of population density may easily be converted into an estimate of density per sq. mile by applying our formula. For instance, an estimate of 200 locusts per man-hour would be equal to an estimate of $200 \times 5280/1 \times 22 \times 3$, *i.e.*, 16,000 locusts per sq. mile.

During 1935, when a large incursion of locusts was found to have occurred on the reks of Pasni, during the summer months, the number of locusts seen was so high and the insects flew up, on account of the high temperatures prevailing, so readily that it was found possible to count them easily as one walked along. As long stretches of reks had to be covered in order to estimate the density in the various parts of the Pasni area, much of the survey work had to be done by utilizing camels. It was found that, while traversing the reks on camelback, the observers could find the locusts flying up just as in the case of the foot-surveys In calculating the results of surveys on camel-back, however, a range of 22 feet on either side was taken into account instead of 11 feet in the case of the foot-surveys, in order to give due weight to the bigger hulk of the camel. The results obtained appeared to tally fairly well with those obtained for foot-surveys. Later on, however, when with the setting in of cooler weather locusts were not found active, and in subsequent years, when locusts were comparatively few in numbers, the formula adopted for camels proved to be unreliable as many of the insects did not fly up readily. Camel surveys were, therefore, discarded for calculating population density, reliance being placed only on the results of foot-surveys.

In general, the areas frequented by locusts are characterized by low scrub vegetation. In certain localities, as in parts of the desert, taller vegetation is met with, but as in the dry season the ground is on the whole open, the formula worked out satisfactorily in all cases. During the rains, however, when the desert is covered by a dense growth of grasses, as also in the case of fairly dense crops like *bajra* (*Pennisetum typhoideum*) and *jowar* (*Andropoghon sorghum*), it was found that the method adopted for calculating hopper populations, viz. by counting the actual number in two or three sample areas, wherein the extent could be exactly determined, was the only one that could be adopted.

Estimating hopper populations. Whereas adult locusts generally make their presence known by taking flight, green hoppers usually hide among bushes and it is necessary that they should be forced out of their hiding places for estimating their numbers. They are inactive when the temperatures are low, and in cold weather it is only when the sun raises the general temperature of the surroundings that they show signs of activity. As in the case of surveys for the adult locusts, the best time for locating hoppers is between 10 A.M. and 3 P.M. in the colder months and between 8 and 11 A.M. and 4 and 7 P.M. in the hot months.

Hoppers of the solitary phase are, as a rule, found scattered among bushes of their preferred food-plants. The only way to arrive at an estimate of the hopper population would be, as experience has shown, to mark out a small area for example 10 ft. by 10 ft., and count the numbers of hoppers jumping out as the bushes are lightly tapped with a stick (Pl. 12). Since the general colour of the hoppers very closely approximates that of the bushes on which they live, they are likely to be missed unless one looks for them carefully. If the area in which the hoppers occur is a large one, two or more sample counts will have to be taken to get reliable data. With the figures thus obtained, the density of population per acre can be worked out, as also the rate of density per sq. mile if needed.

In cases where very large numbers of hoppers are found crowded together in comparatively restricted areas, as for instance in a cultivated field, a correct estimate of the density of the hopper population is essential in order to enable one to draw conclusions as to whether they may lead to incipient outbreaks, and also to serve as a definite basis for comparison. Unfortunately, the cases of incipient outbreaks that occurred in Mekran in 1935 could not be examined early enough to have a determination of the density of the hopper population being made, so that it is not possible to make any statement as to the critical degree of density capable of causing outbreaks. There is little doubt, however, that it is likely to be over a million hoppers per acre.

Estimation of average population density. Owing to the extent of the area to be covered by the surveys, the scattered distribution of the locusts and the limited staff available for survey work, any very precise determination of the density of population for large areas was found to be beyond the bounds of practicability. Only random examinations have been possible, and the surveys carried out can be considered to be only of the nature of 'samplings'. The number of locusts found in particular surveys is ultimately dependent on the peculiarities of their distribution at those times. The results of individual surveys are, thus, liable to vary a good deal, though carried out in the same region. In order to counteract the effects of individual variation and make the figures comparable with those worked out for other regions and other periods of time, it was found desirable to work out the average of the

density of population for the whole area surveyed. For working out the averages, the following method was adopted. The extent, in square miles, calculated for all the individual surveys, irrespective of whether locusts were noticed or not, were added together to get figures of the total extent of the area surveyed. Similarly, the total number of locusts noted in the course of all those surveys was obtained by adding up the individual results, and from these data, the average population density for the whole area was worked out.

Figures of average population density have, in this way, been worked out for the different areas under observation in the regions of Baluchistan, Sind and Rajputana and for the different months. The results have been tabulated for each year separately for purposes of comparison, and are appended in the form of tables for reference.

Value of the present method of estimating population density.

As already stated, the present method does not aim at any high accuracy in the estimates of population density, but is useful in providing a convenient formula by which a rough estimate of the density of locust population at different places and at different times can be made, thus supplying a common basis for comparison in respect of the effect of different environmental conditions.

Moreover, what is wanted is not an absolute census of locusts at any particular place, but rather a rough criterion to indicate whether a significant increase or decrease of population has taken place, so as to decide how far the locust situation in the area concerned has been affected by any local multiplication or an immigration from outside. The experience of the last eight years shows that variations in densities up to 10,000 per sq. mile are not of much consequence, as they represented, in general, a mere fluctuation of population. On the other hand, any increase of population above that limit, especially if it is spread over a large area, should be taken somewhat seriously, as there is a likelihood, if conditions should be favourable, of their leading to the formation of concentrations of locusts in restricted situations, and thus bringing about crowded breeding. In localities where there is a high concentration of hoppers, such as may lead to an incipient outbreak, the density of the hopper population may reach over a million per sq. mile. A further degree of concentration, probably of the order of 20 to 100 millions per sq. mile, is presumably needed for the actual formation of a swarm.

In the course of the last five years, the present method of estimation has been of great value in the study of populations of the solitary phase locust, and it may be expected to be of similar service to the Locust Warning Organization now functioning in India.

Methods of capturing locusts

In the matter of the collection of locusts in the field, there are numerous difficulties, which are well-known to locust workers. The solitary phase locust—with its light stripes on a grey-brown back-ground—blends so well with its surroundings, especially when there are creeping stolons of grasses on the sand, that its presence is many a time not even suspected, until it gives itself away by suddenly taking wing. Especially at times when the temperatures are fairly high, the insect is found so wary that it cannot be caught without considerable effort.

In the *rek* areas of Mekran, where the bushes are generally low and there are numerous open patches of sand in the midst of the desert vegetation, on which the locust loves to sit and bask in the sun, a fairly

easy way of capturing it was devised by the staff at Pasni in 1932. A long stick is taken, and at one end, a piece of old fishing-net of ½ inch mesh, a foot or a foot-and-half square (a longer piece of netting may, in case the meshes are too large, be taken and folded double before being attached to the stick) is tied up somewhat in the fashion of a flag (Pl. 13). When a locust has been located, the observer cautiously approaches it from behind and slowly extends the stick with the piece of netting hanging down till the latter is about a foot or two above the insect, when it is fairly swiftly dropped flat on it. The locust now struggles to free itself from the netting, but is easily captured before it is able to do so. It is rather surprising to find that the locust does not mind the gradual approach of the piece of the netting above its body, but apparently the perceptive faculties of its eyes are limited to the recognition of only violent or jerky movements. In the Rajputana desert also, this method can be successfully adopted, wherever locusts are found in open spaces, but usually the vegetation is so much taller and denser than in the 'rek' areas, and during the monsoon period and for a considerable period after its close, there is such a dense growth of annuals, including the spiny-burred 'Bharut' grass, that the use of the method described above is impracticable. The only way of capturing locusts under the conditions of the Rajputana desert is by the employment of a strong hand net—of the pattern usually used for catching butterflies.

Biometrical characteristics of locust population. A study of the external characters of locusts has shown that specimens of the *gregaria* phase found in swarms are clearly distinguishable from those of the *solitaria* phase in certain respects.

1. Certain parts of the body show clear differences in development in the *solitaria* and *gregaria* phases, which can be concretely expressed in terms of ratios between their relative measurements. For example, the ratio between the elytron and femur (generally shown as E/F ratio) is over 2·15 for the *gregaria* phase in the Desert Locust, and below 2·06 for the *solitaria* and values intermediate between these are found in forms showing a transition in their characters between *gregaria* and *solitaria*, which are often referred to as phase *transiens*.

2. The *gregaria* forms collected from swarms have invariably been found to show six stripes in their eyes, and also 26 segments in their antennae, while in the *solitaria* forms, the number of stripes is in some cases six and in others seven, and in a few cases even eight. The number of antennal segments is 27 in the forms with six eye-stripes and 28-29 in those with seven eye-stripes.

3. The coloration in the *gregaria* forms is pinkish in the immature and bright yellow in the sexually mature stage. On the other hand, the *solitaria* forms are generally grey-brown with longitudinal stripes, and their general body coloration also tends to be lighter or darker in correspondence with its environment.

Collections of locusts secured during visits to well-defined geographical areas were, as a rule, grouped together and subjected to biometrical examination, and notes on various morphometric measurements, the number of eye-stripes and antennal segments and the colour details were individually recorded. A statistical analysis of the results, showing the relative proportions of (1) the three different phases (as determined by the E/F ratios), among the component individuals of such collections, expressed in terms of their percentages, and (2) similarly of 6-striped and 7-striped types, also shown in terms of percentage, has been used to

distinguish between populations found at different places and at different times. This method has proved to be of particular value, as it can show at a glance the relative state of development of the population from the point of view of phase. The following scheme has, therefore, been adopted in the present report to express the distinctive biometrical features of locust populations:—Relative percentages (1) of *Solitaria, Transiens* and *Gregaria* forms shown as S:T:G:, combined with similar percentages (2) of forms with 6 and 7 eye-stripes shown as (6): (7).

For example, a collection of 108 specimens made in the Bahawalpur-Rajputana areas in the autumn months of 1932 showed the following characters, or 'biometrical facies': 67S:29T:L/G:45(6):55(7), indicating a preponderance of *solitaria* ratios and also of 7-striped forms.

680 locusts collected from various parts of the Rajputana desert during the summer months of 1935 showed the following percentages:— 28S: 42T:30G:; 91(6):9(7) indicating fairly large proportions of *gregaria* and *transiens* ratios and a preponderance of 6-striped forms. On the other hand, an analysis of 442 specimens collected in the desert areas during the autumn months of 1935, gave the following biometrical index:— 70S:26T:4G: :40(6):60(7) showing that after monsoon breeding, the entire facies of the population had changed disclosing a preponderance of *solitaria* ratios and 7-stripes.

It will thus be seen that a biometrical analysis of locust collections can be of considerable help in a field study of locust populations. The subject will be dealt with in greater detail under 'Biometrical Studies'.

CHAPTER II

RESULTS OF LOCUST SURVEYS AS CORRELATED WITH WEATHER DATA 1931-36

ACCOUNT FOR YEARS 1931-32

A GENERAL account of the results of the survey work carried out during the period 1931 to 1933 in connection with a study of the distribution and activities of the solitary phase of the Desert Locust in the Indian area will now be given. In the preceding chapter, a brief mention of the extensive tours undertaken during the years 1931 to 1933, as well as of the system of periodic regional surveys adopted since 1933, has been made.

In view of considerations of space, the mass of figures accumulated in the course of eight years' work, on the finds of locusts recorded during surveys, has been omitted, but as far as possible figures showing the average population densities for various areas have been worked out month by month for the different years, (1931 to 1938) and tabulated so as to facilitate comparison, (*vide* Statements I, II, III, IV, V, VI, VII and VIII).

All observations made on locusts and their activities during each year will be reviewed in the following chapters, in conjunction with the prevailing weather conditions, and any definite correlations noticeable between locust occurrence and meteorological data will receive special attention.

YEAR 1931

The year 1931 is particularly interesting as it proved to be the last year of the great Locust Outbreak of 1926-1931, and at the same time paved the way for the commencement of a period of locust subsidence. At the time when the present scheme of locust research began to function, i.e. December, 1930, there were no reports of locust swarms in North-West India. Subsequently, however, they began to reappear, by April in Upper Baluchistan, which led to a temporary suspension of locust surveys, with a view to avoid a complication of issues due to the intrusion of *gregaria* forms. In the Mekran area, however, the swarms arrived very much later, (in June-July), which circumstance proved to be of particular significance, for it proved that the green hoppers discovered in the Coastal Reks of Mekran in May 1931, had developed independently of the entry of swarms from outside and gave definite support to the inference that they were functioning as some of the 'reservations' of the solitary phase.

In Upper Baluchistan, no locusts had been noticed till the end of March, but by April, yellow swarms began to appear in Kharan and Chagai from the direction of Iran, and to lay eggs. Subsequently, they reached Sarawan and Quetta-Pishin districts in May. Swarms of pink locusts bred in Chagai and Afghanistan began to fly in Upper Baluchistan during June and July and seemed gradually to work their way into Sind and the Punjab.

A fuller account of the swarm movements observed in 1931 is given in Part II dealing with the *gregaria* phase of the locust.

Weather notes for 1931

Winter rainfall. Although western disturbances began to appear as early as November 1930, there was little rain till the second fortnight of January, when fairly good general precipitation occurred in the coastal areas of Mekran and in Upper Baluchistan. There was good rainfall throughout Baluchistan during February, and a fair quantity of rain was also registered in March. Some of these disturbances also caused rainfall in the Punjab in January and February, especially in Rawalpindi, Lahore and Ambala areas.

Monthly rainfall data for 1930-31 *season.*

Localities	Nov. 30	Dec. 31	Jan. 31	Feb. 28	March 31	Apl. 30	May 31
Baluchistan							
Pasni .	..	..	2·62	1·90	1·19	..	..
Gwadar .	..	..	2·52	3·10	1·07	..	..
Panjgur .	..	..	0·28	1·39	1·21	0·02	..
Nushki .	..	0·05	0·04	5·10	0·38	0·52	0·08
Quetta .	0·15	0·21	2·22	5·03	1·89	1·03	0·46
Punjab							
Rawalpindi .	0·10	0·01	3·29	2·43	2·61	1·43	2·25
Lahore .	..	..	1·72	0·91	0·99	0·26	0·85

Monsoon rainfall. Although the monsoon commenced on the West coast of India by the 3rd June, it did not extend into North-West India till July first week, when under the influence of a low pressure area over Sind, the current extended into western Rajputana and Gujarat and caused some rainfall in N. W. India. In August, fair to heavy rainfall was recorded in many parts of W. Rajputana associated with the development of four different Bay depressions. Barmer had 21 in. in the course of ten rainy days (with 4 in. on the 18th and 5·3 in. on the 29th), Sanchor, 22·76 in., Deesa 24·78 in., Jaipur 15·23 in., Ajmer 10·23 in., Jodhpur 10·44 in., Sheo 13·50 in., Jaisalmer 7·51 in., Chachro 7·35 in., and Bikaner 5·22 in. There was no rainfall, however, in South Sind and Lasbela. During the first week of September, light rains were received in the desert under the influence of a Bay depression, but by the 10th September, the monsoon practically withdrew from Western Rajputana and the Punjab. There was very little monsoon rainfall in parts of Sind and Baluchistan in 1931.

Monthly rainfall data for 1931 monsoon

Localities	May	June	July	August	September
Sind-Rajputana					
Bikaner	0·43	0·42	5·01	5·22	..
Jaisalmer	1·49	0·62	0·60	7·51	0·31
Jodhpur	0·78	0·29	0·78	10·44	0·05
Barmer	0·76	0·34	0·98	21·58	0·62
Chachro	0·75	..	1·98	7·35	2·87
Baluchistan					
Gandhawa	0·30	..	0·65	0·85	..
Sonmiani	..	..	..	0·03	..
Pasni	..	..	..	..	..

OBSERVATIONS ON LOCUST DISTRIBUTION DURING 1931. (*Vide* Statement I)

I. Winter period, December 1930 *to February* 1931. Survey work was begun only in February 1931, so that no information is available in regard to the *solitaria* locusts either in the Baluchistan or the desert areas prior to February. The Chagai district of Baluchistan, usually the first area to suffer from locusts every year, was examined in February, but no swarms were found. Two locust individuals, evidently over-wintering forms, were, however, discovered one at Ahmedwal and the other near Nushki, during the first week of March.

A small flight was reported on 4th March 1931 at Kabirwala in Multan district and another on the 21st April near Jacobabad in north Sind, from which it is evident that small, scattered concentrations of over-wintering locusts had been existent in south-west Punjab and north-west Sind during the winter months, though there were none in Baluchistan.

II. Spring period, 1931. *The Solitaria Population.* Surveys made around Karachi at the end of March and in mid-April did not reveal the presence of locusts; on the other hand, the survey party met with fairly large numbers of scattered locusts during April in the Lasbela area. At Bela and Sonmiani, concentrations of the density of about 500 to 1,000 per square mile were encountered. While at Uthal only one locust was observed, a single one also at Naka Kharrari (though good numbers were reported to have been seen here a week earlier), and two at Hab-Chowki. In May, the survey party found fairly good numbers of adult locusts, as well as a fair number of green hoppers on bushes. on coastal 'reks' in the neighbourhood of Ormara, Pasni and Gwadar. (Enquiries made in April 1932, at Khandewari, in the south-western part of Lasbela State, indicated that light breeding had occurred after rainfall on the Khandewari Rek. in February-March 1931, as the result of a small incursion of yellow locusts from the western hills). In the interior of Mekran, they did not meet with any adult, locusts either at Turbat or Panjgur, but found a few green hoppers in a lucerne field at Panjgur, and one hopper at Gwargo to the south of Panjgur. One adult and one green hopper were collected at Suntsar in the Dasht River valley on the way to Gwadar. It was reported that. on the whole, half the numbers of locusts in various parts of southern Baluchistan were grey-brown in colour, while the rest were either pink or yellow, the brownish forms being regarded to be all

solitaria, and the pink or yellow ones to be in part *transiens* and in part *solitaria*. Out of a collection of about 500 specimens of adults, the greater part was sent by the party to Lyallpur for the purpose of life-history observations, and only a small number had been preserved. An examination of these, however, indicated, the following biometrical facies: 17S:35T:48G::100(6):0(7), showing that the bulk of the population was actually either *gregaria* or *transiens*, and that all of them were 6-stripped.

It was also observed that most of the *solitaria* specimens had hyaline wings indicating that they had acquired wings quite recently, while the *gregaria* or *transiens* forms had either pinkish or yellow hind-wings, and were, therefore, an older generation, possibly representing the over-wintered stragglers from swarms of the preceding year. The green hoppers found in May on the *reks* of Ormara, Pasni and Gwadar were obviously derived from this over-wintered generation.

The Gregaria Swarms. Swarm movements recorded for the year 1931 will be fully discussed in Part II of the present report, but a brief mention of the salient features of their activities is essential here for correlating them with the observations on the *solitaria* forms.

Yellow swarms were first noted in Kharan on the 6th April and apparently they reached the Chagai area by the 15th April. According to Predtechensky [1935,2], no over-wintering swarms were observed in Iranian Baluchistan and the yellow locust swarms found in southern Iran in April were of Oman origin and had arrived there by the end of March. Evidently the swarms that invaded Kharan and Chagai in April from the direction of Persia were of the same stock, and were likewise of Arabian origin. These swarms first laid eggs in Kharan, Chagai and Panjgur, and then migrated higher up into Shorawak and Kandahar areas in Afghanistan, into Sarawan and Quetta-Pishin in Upper Baluchistan, and into Jhalawan. Fairly heavy oviposition occurred in these areas, especially in Panjpai, Mastung and Pishin during May, large numbers of hoppers being reported therefrom in May-June. The new generation took wing during May-June in Chagai and during June-July in Upper Baluchistan, and considerable flights were noticed during June and July (Pl. 14) in Baluchistan, in the direction of Sind and the Punjab.

III. Summer Period, 1931: Summer breeding in Baluchistan. Owing to the absence of monsoon rainfall in Baluchistan, there was no breeding anywhere—not even in Lasbela and Kachhi which are normally summer-brood areas.

On the other hand, small numbers of green hoppers were found on the following wild bushes: *Chrozophora verbascifolia, Heliotropium eichwaldi,* and *Alhagi camelorum,* and on leaves of 'jowar', in the valleys of Dasht and Spezand, and on the open plains north-east of Quetta during July. It may be mentioned that egglaying by swarms of yellow locusts had taken place in May, in the Dasht Thana area, leading to the appearance of hopper bands during June. While the green hoppers found near Dasht were probably stragglers from the *gregarious* hopper bands, the isolated green hoppers noted at Spezand and near Quetta, possibly represented stray cases of oviposition in favourable situations by individual locusts. In the Spezand area, hoppers were met with till the first week of August after which they were not found, but adult locusts of the solitary type were seen in fair numbers till September,

after which they gradually disappeared, very few being met with in October and none in November. It is not possible to say whether their disappearance was due to emigration or natural death. In addition, it may be mentioned that a few green coloured hoppers were generally found mixed with bands of *gregaria* hoppers in the Chagai area in May, 1931. Though generally found moving along with black hoppers, they showed a tendency to isolate themselves on bushes.

These observations served to indicate that it would not be correct to lay undue emphasis on the appearance of green hoppers in an area as the main criterion for considering whether it can function as a permanent breeding ground of the solitary phase of the desert locust.

Climatic conditions of summer in Baluchistan.—In normal years, the monsoon exerts its influence on the eastern parts of Baluchistan carrying rainfall to the lowlands of Kachhi and Lasbela, and into the valleys of Zhob, Loralai, Sibi, Sarawan and Jhalawan. In certain years the rainfall may extend as far as Kolwa, Kech and Panjgur, and sometimes a depression from the Arabian Sea may cause heavy downpours on the Mekran Coast.

Normally, however, in the interior of western Baluchistan, such as Chagai, Kharan and Mekran, the winter rains come to a close by the middle of April, and between May and September, conditions of high temperature and low humidity accompanied by strong dry winds from the north or north-west prevail, so that like the adjacent parts of Iran, they become regions of severe summer drought.

Monthly data for summer months in Western Baluchistan.

Months	Localities	Maximum Temperature (in degrees Fahrenheit)		Humidity
		Mean max.	Highest max.	Mean at 8A.M.
				Per cent
April	Chaman	81·2	90	40
	Dalbandin	91·1	98	51
	Mirjawa	92·1	101	52
May	Chaman	87·6	96	24
	Dalbandin	98·3	105	35
	Mirjawa	96·9	108	33
June	Chaman	94·4	102	18
	Dalbandin	103·0	111	31
	Mirjawa	102·4	114	35
July	Chaman	98·8	104	68
	Dalbandin	106·5	111	66
17th July	Panjgur		106(Max.)	65 (8 A.M.)

The figures in the above table serve to give an idea of the changes in the climatic conditions noticeable during summer in the hinterland. These changes, however, are not gradual in character, but are manifested as a series of waves. A period of 10 or 15 days of high temperatures may be followed by an interval of moderate climatic conditions, to be succeeded by another spurt of severe heat and drought. Movements of locusts would appear to occur mostly during periods of such a rise of temperature.

Though no observations are available in regard to *solitaria* locusts, reports on the movements of swarms during June, July and August clearly indicated that they were gradually leaving the areas of western Baluchistan and proceeding by stages and, mostly in a series of waves, from west towards east, north-east or south-east, in the direction of Sind, Rajputana, and the Punjab. Along the Mekran coast, certain swarms reached the coastal areas from the interior of Mekran during July.

Large numbers of hoppers and locusts were found by survey staff in Dalbandin, Nushki and Ahmadwal in Chagai district during May, but at the end of June very few locusts were noticeable at Nushki, and during surveys made in this area in September and later on in November, none were to be seen. It is thus obvious that no locusts were practically left in the western areas, such as Chagai, Chaman and Kharan by the end of July.

Summer breeding in the monsoon areas. As no surveys had been undertaken in Sind and Rajputana during the summer months of 1931, no information is available in regard to the activities of the *solitary* phase locusts in these areas. From the experience gained during the years 1933 to 1938, however, one might expect to find them breeding wherever good rainfall had been received, and scattered *solitaria* breeding may be presumed to have taken place in many of the desert areas, independently of the breeding of swarms reported from various parts of Rajputana.

Large bands of *gregaria* hoppers were reported from Mallani and other parts of Marwar, from parts of Jaisalmer, Bikaner, Ajmer, Alwar, etc. in Rajputana, from the districts of Hissar, Gurgaon, Ferozepur, Montgomery, Dera Ghazi Khan and Multan, and from the States of Patiala, Faridkot, Nabha and Bahawalpore in the Punjab, and from the districts of Budhaon, Muttra and Bulandshahr in the United Provinces.

In Makran and Lasbela, as in South Sind and Kacchi, there was no rainfall and consequently no summer breeding.

IV. Autumn Period, 1931: *Solitary locusts Population on the Mekran Coast.* At the end of September 1931, the Pasni area was examined by one of the Survey staff, and about 90 locusts of the non-gregarious type (the density of population being about 300 per square mile) were collected from parts of the Pasni reks. Out of 13 preserved specimens of this lot six were *gregaria,* six *transiens* and one *solitaria.* The *solitaria* specimen had seven eye-stripes, while the rest were six-striped, so that the biometrical index was found to be 8S: 46T: 46G: : 92(6):8(7).

During the first week of October, small numbers of the non-gregarious type were observed on the Ormara reks, and during the second, several specimens of both brown-coloured and pink locusts were collected from the Sonmiani reks. The density was apparently between 200 and 400 per square mile. The only specimen preserved was found to have 2·26 E/F ratio (clearly *gregaria*) and six eye stripes.

As the collections of this time showed a high proportion of *gregaria* components, it is presumed that the population observed in the vicinity

of Pasni, Ormara and Sonmiani was largely composed of stragglers from swarms.

Swarm movements. During 1931, there was comparatively light oviposition in the Punjab and the United Provinces, the main area of breeding being the Rajputana desert. As a result, large numbers of pink locust swarms were present in the desert area during September and October.

STATEMENT I

Results of Locust Surveys, 1931

The figures represent the average population per square mile for the whole month in the areas surveyed and 'H' represents occurrence of breeding.

Season	Months	BALUCHISTAN						
		Mekran					Lasbela	
		Gwadar	Pasni Reks	Ormara	Panjgur	Kulanch Dasht	Ambagh Reks	Hinidan Bela
Winter	December 1930							
	January 1931						..	
	February 1931							
Spring	March 1931							
	April 1931						500—1000	300—500
	May 1931	H 480	H 600	H 300 to 700	H	(Suntsar) H 10		
Summer	June 1931							
	July 1931							
	August 1931							
Autumn	September 1931		300					
	October 1931			120			200—400	
	November 1931	(Swarm)	(Swarm)	(Swarm)	(Swarm)	(Swarm)		(Swarm)

STATEMENT I—*Results of Locust Surveys, 1931 (contd.)*

The figures represent the average population per square mile for the whole month in the areas surveyed and 'H' represents occurrence of breeding

Season	Month	Upper Baluchistan		SIND-RAJPUTANA			
		Chagai	Dasht-Spez-and	S.W. Punjab Bahawal-pur	Thar Malani	Jaisa lm	Bikaner
Winter	December 1930						
	January 1931						
	February 1931	10					
Spring	March 1931						
	April 1931	H (Swarms) Adults (Swarms)		50—150			
	May 1931	H (Swarm) Adults (Swarms)					
Summer	June 1931						
	July 1931		H (Swarm)				
	August 1931		500		H (Swarm) Adults (Swarm)	H (Swarm) Adults (Swarm)	H (Swarm) Adults (Swarm)
	September 1931		180		H (Swarm) Adults (Swarm)	H (Swarm) Adults (Swarm)	H (Swarm Adult (Swarm)
Autumn	October 1931		30		H (Swarm) Adults (Swarm)	H (Swarm) Adults (Swarm)	H (Swarm) Adults (Swarm)
	November 1931		Nil				

The monsoon practically withdrew from northwest India by the 10th September, and as a result conditions of drought developed in the desert by the end of September and intensified during October, as may be seen from the monthly data given below:—

Monthly data for the autumn months in Rajputana

Localities	Max. temper. (Degrees Fahrenheit) Mean: Max.	Max. temper. (Degrees Fahrenheit) Highest Max.	Humidity Mean at 8 A.M.	Dominant wind direction
			Per cent	
September				
Bikaner	96·1	102	67	S.W.
Jodhpur	94·9	103	66	S.W.
October				
Bikaner	92·3	103	51	S.E.
Jodhpur	92·5	101	60	N.E.
November				
Bikaner	85·8	89	33	S.E.
Jodhpur	88·7	92	40	N.E.

Presumably with the development of dry conditions, swarms gradually left the area during October and November, some flying south into the western India States, a few eastwards into the Bundi State in eastern Rajputana, but the major part westwards *via* Jaisalmer and Sind into Lasbela, Mekran and Jhalawan in Baluchistan. By the end of November, however, the swarms had practically disappeared, only a few being reported from southern Sind and Baluchistan during December.

YEAR 1932

Weather notes for 1932

Winter rainfall.—The first western disturbances of the winter of 1931-32 appeared in October, 1931, but did not cause any rainfall except in Kashmir, as was also the case in November 1931. Altogether about 31 disturbances were recorded between January and May 1932 in the Baluchistan area, but few of them caused any precipitation. Most of them, moreover, took a more northerly course than usual, so that there was little rainfall along the coastal areas, whereas a fair amount was recorded in the Kech and Panjgur valleys and in Upper Baluchistan, as may be seen from the following data:—

Monthly rainfall data for winter, 1931-32

Localities	Dec. 31	Jan. 32	Feb. 32	March 32	April 32	May 32
Baluchistan.						
Jask (Iran)	..	0·10	..	0·80	..	..
Pasni	0·73	0·06	..	0·15	0·04	..
Gwadar	1·21	..	..	0·92	..	..
Ormara	0·40	..	..	0·17	..	..
Turbat	0 69	0·14	..	1·56	0·17	..
Panjgur	0·09	0·28	..	0·57	0·21	0·15
Gandhawa	..	..	..	0·58	..	..
Quetta	0·29	0·41	0·64	1·23	0·29	0·38

Monsoon rainfall. Although an advance was noted in May both in the Bay and on the West Coast, the regular monsoon commenced only on the 2nd June on the West Coast, but did not extend till July into North India which, in the meanwhile, suffered from a severe heat wave in mid-June.

A low pressure wave, associated with the strengthening of the Arabian Sea current by the beginning of July, moved northwards through Kathiawar and Cutch into Sind and Baluchistan and caused an extension of the monsoon into the desert areas. The following falls were recorded: Bikaner 2 in. (9th) and 1·1 in. (12th); Barmer 3·7 in. (11th); Karachi 1·2 in. (12th) and 5·7 in. (13th); Khanpur 2·7 in. (14th); Pasni 5;6 in. (14th). With the advance of a Bay depression, there was further rainfall in the latter half of July in Sind and Rajputana: Karachi 1·9 in. (18th); Barmer 3·7 in. (25th). The seasonal trough over the Gangetic plain during the first fortnight of August caused heavy precipitation in North-West India: Jodhpur 5 in. (2nd Aug.) and 6·5 in. (8th); Barmer 1·3 in. (3rd); Badin 2·5 in. (10th); and Jacobabad 2·3 in. (10th). This was followed by a break that lasted from the 15th to 28th August, after which with the advance of two Bay depressions in September there was heavy rainfall in East Punjab: Ambala 6·7 in. (7th Spt.) and 8·3 in. (8th); and Delhi 6·3 in. (24th Spt.). There was, however, no rainfall in the desert areas.

Monthly rainfall data for the monsoon period

Localities	May	June	July	August	September
Rajputana area					
Bikaner	0·47	0·03	4·79	2·78	..
Sardarshahr	0·13	0·64	4·72	3·49	0·34
Jaisalmer	..	0·14	3·02	3·27	0·13
Bap	..	..	4·99	0·20	..
Jodhpur	0·13	0·96	1·57	13·91	..
Barmer	0·60	0·45	7·01	2·93	..
Sind area					
Chachro	..	..	6·83	2·45	...
Karachi	..	..	10·34	0·99	..
Jacobabad	0·10	..	0.70	4·16	..
Baluchistan area					
Gandhawa	..	0·18	2·44	0·76	..
Sonmiani	..	..	3·85	3·00	..
Ormara	..	..	2·23	0·17	..
Pasni	..	..	5·69	..	..
Gwadar	..	..	2·53	..	..

Observations on Locust Distribution during 1932.

(*Vide* Statement II)

1. *Winter Period 1931-32.* During this period, locust surveys were carried out only in (1) the Bolan Valley, Kachhi and Western Sind, and (2) the Mekran coastal areas and the Kech valley and accordingly data on locust distribution is restricted to them.

In the Bolan, Kachhi and West Sind areas, the survey party met with only small numbers of locusts of the non-gregarious type scattered thinly all over the area. The population density varied from 50 to 300 per square mile, though in one or two places it was as high as 1,000 per square mile.

A biometrical examination of 71 specimens showed the following facies:— 51S:31T:18G::100(6):0(7). Owing to the dominance of six striped forms and the presence of *gregaria*, it is presumed that the locusts noticed were mostly stragglers from the autumn flights of 1931 and had been over-wintering here. It was, of course, obvious that these locusts could not have been locally bred individuals, as there was no rainfall in the whole of western Sind and Kachhi during the summer of 1931.

Locusts were also met with in various parts of Mekran during January and February. A good number was found on the coastal reks of Pasni and Gwadar, and several were also observed scattered in the valleys of the Mekran hinterland, especially on the beds of rivers. On the reks, the density varied from 100 to 250, and in the interior, it was low in general, except in the vicinity of Mand, where a good concentration of about 400 per square mile was noted on a part of the bed of the Nihing river. In addition, locusts were seen scattered all over the plain. On the reks, most of the specimens had the typical *solitaria* coloration, with prominent pronotal and lateral brown stripes on a greyish back-ground, but several of them had pink-coloured hind-wings. A biometrical examination showed that the majority were either of the *gregaria* or the *transiens* type. In the hinterland also, the *gregaria* and *transiens* types predominated, and many of them were clearly of pink colour. In a few cases, locusts of very dark colour were found in black gravel areas—locally known as 'Siah-pat.' There is little doubt that the population found in February in Mekran was also mainly composed of stragglers from pink swarms that are known to have visited these areas in October, November and December 1931. The biometrical index based on the examination of 46 specimens was: 10S:36T:54G::98(6):2(7), and showed the predominance of *gregaria* and *six-striped* forms.

Swarm movements. Information is available from Consular reports that thin pink swarms were moving about in parts of eastern Iranian Baluchistan during December 1931 and January 1932, the winter having been milder than usual. A small swarm was reported in January at Panjgur, and another in the Kanrach valley in February. Caravans arriving in mid-February at Turbat gave information that some oviposition had occurred in the Bampusht area of Iran, adjoining Zamuran, in January after rainfall.

II. Spring Period: 1932. Lasbela. In March a fieldman, found a single locust near Liari. In April, the whole of the Lasbela area was surveyed by the motor-lorry party, who did not meet with any locusts, except for two pinkish specimens on the bed of the Porali, 10 miles north of Bela. None were found in May in the Hinidan area also. It may be recalled that large numbers had, on the other hand, been collected from these areas in April, 1931.

West Sind. During March, various localities in the south-western part of Sind were examined, and small numbers of over-wintered locusts were met with, the density ranging from 50 to 150 per square mile. In one locality, near Angare-Gadap, about 20 miles north of Karachi, however, a large concentration of a density of about 1,000 per square mile was encountered on the 29th March 1932. It was found on enquiry that a sharp shower measuring about 0·75 inch had fallen on that area on the afternoon of the 24th March, and it was reported that the ground was fairly wet on the date of the first survey, when 43 specimens were collected within four hours. The soil was fairly coarse loam, with drift sand heaped up at the base of the scattered plants. The vegetation consisted of stunted bushes of *Prosopis spicigera, Cordia rothii, Acacia senegal, Lycium barbarum, Indigofera paucifolia, Grewia sp., Aerua javanica* and

Zizyphus nummularia. As most of the locusts collected were taken to Lyallpur for purposes of life-history studies, and as few specimens had been preserved, it is not possible to make any definite statement on the affinities of this population. An examination of the available specimens has, however, shown that both *solitaria* and *transiens* types were represented therein. It may be presumed that the thunderstorm rain of the 24th March had brought about a concentration at that spot, of a large number of over-wintering locusts from the surrounding areas, and since green hoppers were found in this area on bush vegetation (mostly *Cordia Grewia, Zizyphus* and *Lycium*), early in May, it would appear that oviposition had followed. The hopper population was comparatively sparse and the breeding was, on the whole, very light. Fresh adults were noticed by the third week of May, but by July, they had completely disappeared.

Mekran. As a result of the failure of winter rains all along the coast of Mekran, no breeding was observed on any of the reks in the Ormara, Pasni, Gwadar and Pishukan areas. During March, fairly good numbers of solitary locusts were observed at Pasni, a few in the Ormara area, and a good number (average density being about 310 per sq. mile) in the Gwadar-Pishukan-Jiwani area. A collection of locusts made at Pasni and Gwadar during March-April, 1932, consisting of 25 specimens, indicated the facies:—41S:38T:21G::68(6):32(7). By the end of April, the population had greatly diminished both in the Pasni and the Gwadar-Pishukan areas, and by the middle of May no locusts were to be seen.

Locust incursion. On the 24th May, 1932, the Pasni Locust Station recorded the occurrence of a severe dust-storm that commenced at 2-30 a.m. and continued till about 3 p.m. The general direction of the storm was from North-north-east, and the velocity as recorded at the Pasni Post Office was about 30 miles an hour. The wind was dry and hot, and even at the outset (3 a.m.) the air temperature was 37·7°C (100°F) and the humidity was 4 per cent. The maximum screen temperature for the day at Pasni was 115°F, while at Gwadar, Ormara and Karachi, it was 112°F, 117°F and 116°F, respectively. Similar dust-storms had apparently occurred at all these places on the same day.

On the afternoon of the 24th and on the morning of the 25th May, there was recorded a catch of five locust individuals of a brilliant yellow colour, such as had not been seen till then at Pasni. Since then, further specimens of yellow locusts were noticed every day, and by the first week of June, fifty-six specimens had been collected. By the second week, the yellow forms were found disappearing, and in their place, locusts of pinkish colour, as well as grey-brown forms of the *solitaria* type, were being met with in small numbers on the Pasni reks. A biometrical analysis of 16 specimens preserved showed the index:—0S:44T:56G::100(6):0(7), indicating that the yellow forms, as well as the pink ones, had high E/F ratios and were all six-stripped.

Considering the circumstance that no locusts had been met with on the Pasni reks for sometime prior to the 24th May, and that yellow or pink individuals had not been seen till then, it is fairly obvious that a migration from the hinterland had occurred. The bright yellow forms, evidently, represented the over-wintered generation, while the pink ones clearly belonged to a recently developed brood, resulting from eggs laid by the old forms after spring rains. The migration, moreover, appeared to be of the nature of an incursion o individual locusts, as no swarms had been observed at that time anywhere in Mekran. An examination of the Ormara and Gwadar-Pishukan areas in July revealed the presence of several pink and grey-coloured forms, and at Gwadar a few yellow ones

were also noted. Enquiries made indicated that on the 24th May, a severe dust-storm from the north-east had similarly been experienced in these areas, and the presence of the pink, yellow and grey forms clearly indicated the occurrence of a similar incursion.

III. Summer Period: 1932. Sind. A report was received that a small flight of locusts had been seen about the middle of June in the vicinity of Karachi, and on enquiry, the Mukhtiarkar of Karachi sent two specimens of pink-coloured locusts possessing hyaline wings with a suffused pink tinge at base, 6 eye-stripes and E/F ratios 2·17 and 2·23. The locust survey party touring in east Sind, during May-June, did not meet with any locusts till the middle of June, when within the limits of the Khairpur State, fair numbers of pink locusts were noticed and the biometrical index of 24 specimens collected was:—0S:12T:88G: :100(6):0(7). Most of them had high *gregaria* ratios and all had six-striped eyes. The wings were pinkish hyaline. About 20 specimens with the colour pattern of the *solitary* type were found by Mr. Baweja at Akil near Larkana on the bed of the River Indus on the 5th July, but an examination of two preserved specimens showed that the ratios were 2·26 and 2·12, indicating that they were more or less akin to the population found on the opposite bank of the river in the Khairpur State. Akil was revisited by Baweja on the 19th August, but as the whole area was flooded by freshets in the river, no locusts were found, nor any even in the Khairpur area, where good numbers had been seen in mid-June.

Lasbela. No locusts had been met with in early May, but during the next survey by a fieldman on the 20th July, fair numbers of locusts were noticed on the Sonmiani reks. Some of them were yellow in colour, while the majority were grey-brown with pink or yellow wings. A single preserved specimen of this batch showed high *gregaria* ratios and six eye-stripes.

Origin of the incursion. Since pink forms are reported to have made their appearance on the Pasni reks only by the second week of June, it would appear as if the apparition, more or less at one time, of the small pink swarm at Karachi, of the numerous pink or pinkish-grey forms in the Khairpur and Akil areas, of the pink locusts found at Pasni, Ormara and Gwadar, and, presumably, of similar individuals in the Lasbela area, was, in reality part of a widespread incursion of isolated individuals from the interior of Baluchistan into the coastal areas of Mekran and Lasbela, and into western Sind. Apart from the pink colour, the locusts collected at this period from various areas had certain almost identical biometrical characteristics, apparently indicating their origin from a homogeneous stock developed in the interior of the Iranian region. The predominance of *gregaria* ratios is strongly suggestive of crowded breeding at the place of origin, but with the scanty data available it is difficult to say where the breeding had occurred or as to how it had come about.

The winter rainfall of 1932 was scanty, on the whole, in the Baluchistan areas, especially along the coast, but in the interior fairly good rain was received during the months of January and March. It is known that small swarms were active in parts of Iranian Baluchistan during January and that light oviposition had occurred at the end of the month. It is likely that, as observed in the Kech valley in Mekran during February, stragglers from swarms were present in eastern Iran in the form of a large, though scattered, population of *gregaria* and *transiens* individuals,

and that with the fall of rain in March, a concentration of locusts had been brought about, as at Angare-Gadap in Sind in March, followed by crowded breeding wherever conditions were favourable.

As a result of such breeding, it may be postulated that a fairly large population of a newly developed generation of locusts was present in the interior of British and Iranian Mekran during May and June. The following data extracted from the monthly reviews of the India Meteorological Department for 1932 may serve to furnish an idea of the weather conditions prevailing during the period April to July in the interior of Baluchistan.

Monthly data for April-July, 1932 in North Baluchistan

Localities	Maximum temperatures			Humidity at 8 A.M.	Dominant Wind Direction	Cloudiness
	Mean Maxm.	Highest Maxm.	Date of Maxm.			
	(Degrees Fahrenheit)			(per cent)		
April 1932						
Chaman	81·6	92	15 iv	29	S.E.	3·2
Dalbandin	90·0	101	14-15 iv	39	S.W.	1·9
May 1932						
Chaman	88·0	101	22-23 v.	24	S	1·7
Dalbandin	98·3	110	22 v.	42	Calm	0·7
June 1932						
Chaman	95·8	102	18-20 vi	27	S.W.	0·1
Dalbandin	104·9	111	18-19 vi	36	S.W.	0·0
July 1932						
Chaman	97·5	105	7-8 vii	43	S.W.	3·2
Dalbandin	105·1	112	8-25 vii	48	N.W.	2·3

Data are available only for Chaman and Dalbandin, which may be considered representative of the conditions of northern and north-western parts of Baluchistan respectively. From these data, it is apparent that there had been gradual rise of the mean maximum temperature between April and July. The figures of humidity are fairly low during April, May and June, but in July there seems to have been a rise due to rainfall, and considering that the data refer to 8 a.m. observations, when humidity is relatively higher, the afternoons should have been considerably drier.

In May, the highest maximum temperature for the months was reached on the 22nd both at Chaman and Dalbandin. This was presumably connected with a heat wave that prevailed at the time in north-west India, marked by high maxima in north Sind, Punjab and Rajputana, and with various dust-storms from a north-eastern direction accompanied by high temperatures that prevailed on the 24th at Pasni, Ormara and Gwadar, as well as at Karachi.

In mid-June again, another sudden rise of temperature would appear to have occurred in the interior of Baluchistan as signified by the highest maximum at Chaman and Dalbandin on the 18-19 June, and it is not improbable that the incursion of pink forms in mid-June into the Mekran coastal areas and into western Sind had been connected with this heat wave. It is presumed that the development of high saturation deficiency in western Baluchistan, as a result of this heat wave, had made conditions of life so intolerable as to cause locusts to quit these areas by taking flight, and it is conjectured that their migration had been guided by the direction of the dominant wind prevailing up to a height of about 500 feet above the ground.

Swarms. In June, there were four reports of small pink swarms, of which three were from the Kathiawar and Palanpur areas (18-20 VI) and one from the Bahawalpur State (24-29 VI), all possibly organically connected with the locust incursion described above.

Summer Breeding in 1932. As a result of a favourable monsoon, summer rains extended far into the Baluchistan interior during July, not only Lasbela, Kachhi, Jhalawan and Kolwa, but also the strip along the Mekran coast as far as Gwadar, receiving good rainfall.

(a) *Breeding in Mekran.* At Pasni, where continuous observations were in progress since January, 1932, a steady increase of population was noticeable during June on the reks by an immigration of pink and grey forms from the interior of Mekran. Collections made at Pasni during July and August showed a fairly high admixture of individuals with *solitaria* ratios, the biometrical facies being:—46S:23T:31G: : 84(6): 16(7). This would indicate that forms with 7 eye-stripes and *solitaria* ratios had gradually found their way into the area from outside, since June.

While pink forms were prominently seen in the middle of June, few could be found on the reks during July. Field notes of the Pasni staff indicated that they were becoming gradually transformed into forms of grey-brown colour with distinct stripes of the *solitaria* pattern, the pink colour being seen only at wing-bases. Experiments carried out at Quetta and Pasni in 1932 (Sect. IV. Chap. I) fully confirmed these field observations, since typical pink forms without eye or body stripes enclosed under semi-natural conditions in cages and kept exposed to the sun, were found gradually assuming the typical *solitaria* coloration with distinct eye-stripes in the course of a week or ten days.

Rainfall and breeding. Associated with a depression from the Arabian Sea, rain began to fall on the 10th July in parts of the Mekran coast. The main fall occurred on the 13th at Pasni (6·16 in.) at Ormara (3·07 in.) and Gwadar (2·53 in.). Sonmiani recorded 3·85 in. at this time. Owing to the failure of the winter rains, the coastal reks were in a fully parched condition at the beginning of July, but heavy rainfall in July entirely changed the situation. It led to the revival of the dried rek bushes and to the sprouting of annuals, and simultaneously also to the stimulation of the reproductive activity of the locust. Eggs were apparently laid by some individuals almost immediately after the fall of rain, for the earliest batch of hoppers was found to emerge on the 30th July, indicating that the eggs had been laid by the 16th or the 17th July. Emergence continued till the end of August. The earliest adult of the new generation was noted on the 1st September, and hoppers were present on the reks till the middle of October. Adults of the old brood were noticeable till mid-September, after which only the new generation could be seen.

The hoppers were of the green type, with the exception of a few which showed brown patches; those found in the later stages, when the annuals had begun to dry up, were generally of fawn colour. Hoppers of the *gregaria* coloration were not noted anywhere.

As the rainfall had been general on the coast, similar breeding occurred also on the other reks of Mekran. There was good breeding on the Rumra-Gazdan reks, but only small numbers of hoppers were observed at Ormara as also on the Gwadar-Pishukan *reks*, owing to lighter rainfall. Fairly general breeding was noted in the Kulanch area at Nokbur, Kappar and Kandasole, and some hoppers were also found in the Shadi Kaur valley.

No breeding was observable in the Kech valley at the beginning of September, but in Kolwa, hoppers were found in small numbers in several localities, mostly on *Chrozophora* and *Aerua*, as also fair numbers of fresh adults, indicating that light breeding had occurred here in summer.

(b) *Lasbela.* During July and August, locusts were found on good numbers at Sonmiani and Naka-Kharrari, and following fairly heavy rainfall considerable breeding was observed all over the *reks* stretching from Dhamb to Naka-Kharrari. Hoppers were first noted in August; and were noticeable at Naka-Kharrari till the last week of October. In October, a fairly large locust population was present on the Lasbela coast.

(c) *The Sind-Rajputana Desert Area.* This vast area was not surveyed till the end of the rains, so that no data are available on summer breeding of locusts in these areas. Since, however, good rainfall had occurred during July and August in the Thar area of Sind, in the Mallani, Bikaner and Jaisalmer areas of Rajputana and in the Bahawalpur and Dera Ghazi Khan districts of Punjab, and since a fairly high population of recently developed locusts was noticed by survey parties in these areas during October, November and December, it is evident that fairly extensive, though scattered, breeding had taken place in these areas. The biometrical index based on 29 specimens was 71S:29T:OG: :24(6):76(7).

IV. Autumn Period: 1932—Mekran. Definite information on locust activities in Mekran is available only for Pasni. During September, the population gradually increased as hoppers changed into adults and the density at the end of September was roughly about 1,000 per square mile. In October, there was an appreciable rise, the density being about 2,000 per square mile. Hoppers were not noticeable by the end of October. During November, northerly on north-easterly winds prevailed, and a gradual fall in the population was noticed. On the 13th November, it was about 1,290 per square mile, and on the 28th, about 600 per square mile. There was a further apparent fall in December, which may possibly merely indicate their inactivity under winter conditions.

During November, a certain number of locusts were observed to have pinkish hind-wings, which had not been seen on specimens collected during the previous month. Experiments carried out in 1935-37 have clearly shown that pink or mauve colour at the base of the hindwings is a clear symptom of migration. The diminution of population in November, as well as the presence of pink-winged forms, would indicate that a migration had been in progress at that period, especially as north-easterly

winds, which are the usual concomittants of autumn movements, were prevalent during November and December. Presumably the pink-winged forms had arrived from the east or the north-east into Pasni and been migrating westwards.

A collection of locusts made at Pasni and in Kalwa during September showed the proportion of the phases to be as 47S:35T:18G, indicating an increase of *solitaria* forms. Unfortunately very few of the forms found in October and November at Pasni have been preserved, so that it has not been possible to produce biometrical evidence in respect of their migratory movements.

Lasbela. The fieldman at Sonmiani reported the occurrence of fair numbers of adults in the interior of Lasbela (Bela and Kanrach) and of larger numbers in the coastal *reks* in October, but during November, he found a great diminution in numbers.

Sind-Rajputana Area. Various areas of S. W. Punjab, West Sind and Rajputana were examined during October, November and December 1932. No locusts were found in October at Barkhan in east Baluchistan, but in the Dera Ghazi Khan district quite large numbers of a new generation were met with. While some of them might have been migrants from Rajputana, a good number of them had probably developed locally. Similarly, good numbers of locusts were observed at various places in north Sind, the Bahawalpur State and in the desert areas of Bikaner. A biometrical examination of 54 preserved forms gave the analysis:—63S:33T:4G::35(6):65(7), indicating a preponderance of *solitaria* and 7-striped forms.

Another survey party under the charge of the writer, working in the desert areas, found small numbers of adults of a recent brood in western Thar, and the small collection made during October indicated the following facies:—(10 specimens):50S:40T:10G::60(6):40(7). None were met with in the eastern parts of Thar, as for instance near Chachro, nor were any detected in the Mallani area, during the first fortnight of November. It is presumed that, owing to the lack of rainfall since 15th August and the early commencement of dry conditions, the locusts produced in the Thar-Mallani area had to a great extent emigrated. In the Jaisalmer area, locusts were met with only on a large patch of prairie land, covered thickly with large clumps of grass, mostly Siwan (*Elionurus hirsutus*), and Murt (*Panicum turgidum*), between Sodakhor and Jethi, on 28 November. The area formed part of a rolling desert plain, marked by long and low undulations. Out of 19 specimens observed, 11 were caught, and in addition few specimens of the solitary phase of *Locusta migratoria* were also found. Biometrical analysis gave the following index:—(10 specimens) 70S:30T:OG::60(6):40(7).

A similar collection made by Mr. Baweja in the Pugal area of Bikaner on the 3rd, 4th and 5th December, gave the following analysis:—18 specimens:: 56S: 39T:5G::50(6):50(7). No locusts were, however, found in the interior of the Bikaner area, and it may be presumed that with the exception of a few left on the fringes of the desert as at Pugal, the new generation bred in the northern parts of the desert had mostly migrated.

Weather data for the autumn months. The following weather data may serve to indicate the conditions under which the autumn emigration of locusts had presumably occurred.

Monthly data for the autumn months in Rajputana

Localities	Maximum temperature		Date	Humidity at 8 A.M.	Dominant Wind Direction	Clond amount
	Mean Max. (Degrees	Highest Max. Fahrenheit):				
August 1932.				(per cent.)		
Bikaner . .	92·5	101	31-viii	75	S.W.	3·4
Jodhpur . .	89·1	100	31-viii	82	S.W.	8·1
Barmer . .	88·7	99	31-viii	82	S.W.	6·2
September 1932.						
Bikaner . .	103·2	109	3,4-ix	54	S.W.	0·7
Jodhpur . .	97·8	106	4-ix	64	S.W.	3·5
Barmer . .	98·3	105	5-ix	77	S.W.	2·6
October 1932.						
Bikner . .	99·2	105	2,3-x	17	S.W.	1·0
Jodhpur . .	98·2	102	2,3-x	39	N.E.	2·3
Barmer . .	97·9	105	2-x	53	N.W.	1·5
November 1932.						
Bikaner . .	89·3	97	2-xi	19	S.E.	0·6
Jodhpur . .	89·8	98	2-xi	27	N.E.	0·9
Barmer . .	89·2	96	1,2-xi	51	N.W.	0·5

N.B.—North-easterly winds commenced at Karachi and in Rajputana generally from the th October and prevailed off and on during the month. In November, north-easterly winds were recorded almost throughout the month. At Pasni, northerlies were recorded from the 3rd to 7th, and north-easterlies between 15th and 21st. Again N.E. winds prevailed from 1 to 10, 17-19 and 25-27 November.

Summary of events

Summing up, the main events of 1932 may be stated to be (1) the occurrence of a drought in winter and spring in the areas of Baluchistan, associated with a general absence of spring breeding of the solitary locust, (2) the occurrence of a fairly large incursion of locust individuals, mainly of the *gregaria* phase, in May-June, on the Mekran Coast, in western Sind and, probably, also in western Rajputana, presumably originating, from a western breeding ground, situated perhaps in eastern Iran, (3) summer breeding of the solitary locust in Mekran, both on the coast and in the interior in the wake of an abnormal burst of summer rain in July; as also in Lasbela, western Rajputana and south-west Punjab as a result of satisfactory monsoon rainfall in July-August, (4) the disappearance of locusts in many parts of the Rajputana area by the end of the year, presumably by a shifting of the population westwards in autumn, and (5) a gradual change in the facies of the population from a dominant *gregaria* character in the early part of the year to that of an essentially *solitaria* type by the end of the year.

STATEMENT II

Results of Locust Survey 1932

(The figures represent the average population per square mile for the whole month in the areas surveyed and H represents occurrence of breeding)

Seasons	Months	BALUCHISTAN									SIND			RAJPUTANA		
		Gwadar Pishukan	Pasni Reks (Intensive surveys)	Ormara	Kech Panjgur	Kulanch Dasht	Kolwa	Hingol	Ambagh Reks (Intensive surveys)	Hinidan-Bela	S. Sind	W. Sind Kachhi	S.W. Punjab Bahawalpur Khairpur	Thar Mallani	E. Jaisalmer	Bikaner
Winter	Dec. 1931															
	Jan. 1932			Nil								33				
	Feb. 1932		240	12								33				
Spring	March 1932	310	160	14		107			10		34	92				
	April 1932		48			Nil	(H)		Nil	10	H 470					
	May 1932		48						Nil	Nil	H 24					
Summer	June 1932		613									4				
	July 1932	620	H 705					40	200	Nil		26				
	August 1932.		H Nil	H Nil	Nil			171			Nil	Nil				

STATEMENT II—*contd.*

Seasons	Months	BALUCHISTAN									SIND			RAJPUTANA		
		Gwadar Pishukan	Pasni Reks (Intensive surveys)	Ormara	Kech Panjgur	Kulanch Dasht	Kolwa	Hingol	Ambagh Reks (Intensive surveys)	Hinidan-Bela	S. Sind	W. Sind Kachhi	S.W. Punjab Bahawalpur Khairpur	Thar-Mallani	Jaisalmer	Bikaner
Autumn	Sep. 1932	210	H 680				H 53		H 444							
	Oct. 1932		1913	H 200					H 2040	67		38	107	(Thar) 40		
	Nov. 1932		907						400	800		Nil	47	(Mallani) Nil	100	

CHAPTER III

ACCOUNT FOR YEARS 1933-34

YEAR 1933

Weather notes for 1933

Winter rainfall, 1932-33. Over 42 disturbances made their influence felt in Baluchistan and north-west India, between September 1932 and the middle of May 1933, but there was little rain, till the middle of February 1933, when there was heavy rainfall in Baluchistan especially in Mekran, due to the development of a deep depression along the coast, Pasni and Gwadar recording about 6 inches each. There was but light rainfall in March, but the second disturbance in April gave rise to wide-spread thunder-showers in the regions of the Persian Gulf and the Gulf of Oman. It lay as a depression on the 3rd over Baluchistan, and caused heavy rainfall in many parts of Mekran, Jask reporting 2·96 inches, Gwadar 3·30 in., Pasni 5·37 in. and Ormara 3·02 in. There was a fair amount of rain also in the interior of Baluchistan. May was, on the whole, dry.

Monthly rainfall data for winter, spring 1932-33

Localities	Dec. 32	Jan. 33	Feb. 33	March 33	April 33	May 33
Baluchistan.						
Jask (Iran) . .	1·90	0·90	2·00	..	3·00	..
Pasni . .	0·20	0·21	6·14	0·17	5·37	..
Gwadar . .	0.88	2·40	5·70	0·70	3·30	..
Ormara . .	..	0·39	3·58	0·03	3·02	..
Turbat . .	0·05	0·95	5·12	0·85	3·19	0·60
Panjgur .	..	0·32	1·68	1·37	1·48	0·45
Gandhawa . .	..	0.06	0.35	0·23	0·09	0·19
Quetta . .	0·42	1·63	1·54	1·35	1·14	0·86

Monsoon rainfall, 1933. With an early advance of the monsoon over the Indian seas, rains commenced in Malabar as early as 22 May. It was, however, not until the third week of June that the current reached Gujarat, Rajputana and the Punjab. By the end of June, good rainfall had occurred in most parts of north-west India, excepting Sind and Lasbela. During the second and third weeks of July, fair to heavy rainfall occurred in Sind, Gujarat, Cutch and southern Baluchistan, under the influence of two Bay depressions. Karachi recorded about 12 inches of rain within 48 hours. During August, also, there was widespread rainfall in northern India under the influence of two Bay depressions. Further rainfall occurred during September in association with three depressions. The monsoon withdrew from northern India by the 27 September.

Monthly rainfall data for the monsoon period, 1933.

Localities	May	June	July	August	September
Rajputana Area.					
Bikaner	0·30	1·38	2·87	11·65	0·22
Sardarshahr	0·44	1·62	0·68	6·80	2·32
Jaisalmer	0·08	1·45	1·72	6·46	0·03
Bap	1·00	..	1·95	12·45	..
Jodhpur	1·19	3·39	1·60	15·19	1·61
Barmer	0·27	4·24	2·03	4·93	0·72
Sind Area.					
Chachro	0·70	0·65	4·78	3·11	1·20
Karachi	0·91	..	15·50	3·44	2·67
Jacobabad	0·19	..	3·10	2·00	..
South-West Punjab.					
Bahawalpore	0·14	..	0·45	3·39	0·56
Khanpur	0·07	..	2·56	3·70	0·60
Dera Ghazi Khan	0·43	0·62	1·49	5·01	1·06
Multan	0·18	0·02	0·36	2·13	3·36
Baluchistan Area.					
Gandhawa	0·19	..	0·81	1·87	..
Sibi	0·55	0·03	1·88	0·93	..
Bela	1·34	..	4·60	2·54	3·25
Sonmiani	..	..	9·00	0·50	0·57
Ormara	..	..	0·80	0·50	0·04
Pasni	..	..	0·67	0·02	..
Panjgur	0·45	0·30	1·62	0·02	..
Turbat	0·60	..	1·22	..	..

Observations on Locust Distribution during 1933

(*Vide* Statement III)

I. Winter Period 1932-33. The programme of preliminary surveys was completed only by the end of March, 1933, and the system of regular regional surveys recommended by the Locust Committee did not function till the beginning of June, 1933, so that the information available for the period prior to June is somewhat patchy.

At Pasni, however, where continuous observations were being carried out by the station staff, data for the winter and spring periods are available. Fair numbers of locusts were being met with except on days when

the cold north wind (*Gorich*) was blowing. The density varied from 480 to 50 per square mile and a gradual decrease in numbers was noticeable between December 1932 and February 1933. From an examination of the few specimens preserved, it would appear that the population of this period included all the different phases and that 6-eye-striped forms predominated. Some exhibited pink or mauve colour on their hind-wings indicating that they were migrants, but none showed sex activity presumably owing to the absence of rainfall till the 22nd February.

During a tour in January, in Kulanch, Dasht, Gwadar and Turbat areas, three locusts were met with in Kulanch and two more on the Gwadar reks, and none in Kech. In Lasbela a few locusts with yellow hind-wings were met with in January near Sonmiani during the first fortnight, and small numbers at Khandewari, Sangal, Pohr and Hingol during the second. During February, fair numbers were observed at Naka-Kharrari and a few at Hab-Nadi.

In Sind and Kachhi areas, surveys carried out in January and February at Kundalani in the Bolan valley, at Akil in Larkana, at Thari in Khairpur State, and at Kotri, Thano Bulakhan and Angare-Gadap in south Sind, did not reveal the presence of locusts indicating that, unlike the previous year, no over-wintering had occurred in these areas during the winter of 1932-33.

In the Rajputana area, Bikaner and Jaisalmer were visited during December, 1932 and eastern Marwar, Sirohi and Palanpur during February 1933, but no locusts were encountered, except in the high-dune areas of Pugal in December, 1932. The locusts found at Pugal were, as already stated, mainly of the *solitaria* type, and as a fairly good percentage of the forms preserved had pink or mauve wings, migration had presumably been in progress at the time of collection.

II. Spring Period, 1933. Mekran. At Pasni, with about 6 inches of rainfall on 22nd and 23rd February, quite a large number of female locusts showed evidence of maturity. The first hoppers were collected on the reks on the 10th March, indicating that eggs had been laid in some cases almost immediately after the fall of heavy rain. Green hoppers were being met with throughout March and April all over the Pasni reks in varying numbers and the first adult of the new generation was collected on the 23rd April.

Further rain (about 6 inches) was recorded on 3 and 4 April, which apparently served to bring about conditions favourable for a prolonged breeding. Not only were further batches of eggs laid by the old generation, but even the new brood—which was met with in good numbers by the first week of May, apparently reached sex maturity sufficiently quickly to be able to lay eggs by the middle of May, and, in fact, some of the new adults collected from the reks on the 28th April and kept caged under conditions approximating nature were found to have laid eggs by 9 May. On the general reks, very few hoppers were noticed by the end of June, but in certain special areas of the reks, where the requisite moisture was present in the sandy soil, as also fairly luxuriant vegetation, and conditions were thus favourable for extended breeding, hoppers were being met with till the middle of September.

As a result of the local multiplication, the population on the Pasni reks was found to have increased by the end of May, the average for the month showing a density of about 546 per square mile. As the coastal depressions that caused heavy rainfall at Pasni in February and April, also

occasioned widespread rain in the interior, conditions were obviously favourable for locust breeding all over Mekran. During March, a fairly high locust population was noted in the Ormara area, and by the middle of May, fairly large numbers of green hoppers, as well as of adults of the new generation, were found on the Gazdan, Basole and Ormara reks. Though at the end of March, no locusts had been seen on the Gwadar Pishukan reks, fairly good numbers of hoppers and freshly moulted adults were found there during the second fortnight of May. In Kulanch, green hoppers of the IV and V stages and small numbers of fresh adults were met with in the first week of May, at Sardasht and Nokbur. A few hoppers and adults were also collected in the Shadi Kaur valley in April, and some adults in May at Ghulamani Bent. At the end of May, a fieldman noticed a fairly dense population all over the Kolwa valley, and since a hopper of the fifth stadium was also found at Rodkan, it is evident that breeding had taken place in Kolwa during April and May.

As the locusts of this period were not preserved, no data are available on the biometrical characters of the population.

Lasbela. Regular surveys were not undertaken in this area till the Ambagh Field Station was opened in June. During casual surveys made in the rek areas of Sonmiani and Naka-Kharrari, a few locusts were met with during March and April and only one specimen in May.

Sind, Kachhi and S. W. Punjab. In March, 1933, the Dera Ghazi Khan district in the Punjab was examined and 3 specimens were located at Taunsa, 7 at Tibbi Kasrani and none at Dera Ghazi Khan. Of the six specimens preserved, three were *solitaria*, two, *transiens* and one, *gregaria* and, four were 6-striped and two 7-striped. Three specimens showed a pink tinge in the hind-wings, indicative of migration. None were found in March in parts of the Bahawalpore State.

On the 1st of May, one male specimen (with *solitaria* ratio—E/F 2·02, and 7-eye-stripes) with light yellow wings was found at Gandhawa. None were found at Bhag and other places in Kachhi. Baweja found another male specimen with *solitaria* ratio (2·04) and light yellow wings at Akil near Larkana, but none at Thari in Khairpur State.

Cutch and Thar Desert. In the course of a survey of the Palanpur, Radhanpur and Cutch States in March, only one specimen of the Desert Locust was met with at Mandvi, where in addition four specimens of the Bombay Locust—*Patanga succincta* were collected. Another specimen of *Patanga* was found at Radhanpur. On the way from Bhuj to Badin in Sind, two locusts of the solitary phase were collected at Rahim-ki-Bazar at the extreme south-west corner of the Thar Desert.

III. Summer Period, 1933. Dera Ghazi Khan District. In June, no locusts were met with at Dera Ghazi Khan and Taunsa, nor any in July at Mithankot and Chachran.

West Sind. In the Thano Bulakhan area, three locusts were met with on the 25th June on the Baran river-bed, two more near Thano Bulakhan on the 27th and one on the bed of the Naing stream on the 2nd July. Of the three specimens collected, two had almost transparent wings indicating recent fledging, and all of them showed pink or bluish tinge on the wings—an evident sign of migration. On the 31st July, he found three locusts in the neighbourhood of Larkana, of which two were captured. As the wings were hyaline or light yellow with a tinge of mauve or pink at the wing-bases, they were presumably migrants.

Bahawalpur State. 8 locusts were noticed on the 19th, 20th and 21st June at Fort Abbas on the fringe of the desert, and of the 5 specimens collected, nearly all had hyaline or light yellow wings, with a tinge of pink in some. All were either *solitaria* or *transiens*. Both types of eye-stripes were represented.

Bikaner Area. In July, 9 locusts were observed between the 1st and the 3rd July in the Pugal high-dune area, and 3 more on the 4th between Mehrasar and Badrasar. On the 7th and the 8th, 21 specimens were found around Sardarshahr, and two more on the 14th and the 15th at Nohar. Over 11 specimens were collected in the areas around Bikaner in the later half of July. Out of a batch of 41 locusts collected in these areas during July, 32 were *solitaria* and the rest, *transiens;* and the biometrical facies was 78S: 22T:OG: :74(6):26(7). While most of those collected in the later half of July had deep yellow wings, many of those found earlier in the month had a tinge of pink at wing-bases.

In the light of the experience gained in respect of the migration of solitary individuals in 1935, (Rao, 1936), the biometrical evidence adduced above would indicate that the locust population located in June and July in Sind, Bahawalpur and Bikaner areas represented a recently developed generation that had immigrated from outside, presumably from the winter rain areas on the west.

In this connection, the meteorological conditions recorded at various stations in western Baluchistan and in the Kachhi area for April-July, extracted from the Monthly Weather Report for 1933, are given below:

Monthly meteorological data for April-July 1933 in Western Baluchistan

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain
	Mean maximum in Degrees F.	Highest maximum in Degrees F.	Date	8 A.M.	5 P.M.	8 A.M.	5 P.M.		
				per cent	per cent				Inches
April 1933.									
Dalbandin	86·5	95	25-iv	51	24	NE	S; SW	1·8	0·34
Seistan (Iran)	86	94	29-iv	61	34	N;NW;NE	NW;W;NE	2·4	0·10
Panjgur	86·2	92	23-iv	57	45	NE;SW	SW;W	2·5	1·48
Pasni	89·7	97	18-iv	68	82	W;NW	W; SW	2·7	5·37
Sibi	95·4	104	30-iv	53	..	N;E; NW	..	3·9	0·15
May 1933.									
Seistan (Iran)	97	104	31-v	43	29	N; NW	N; NW	1·7	0·01
Nokundi	104	113	29-v	50	37	Cm; NE; N	NW; N	1·1	0·16
Dalbandin	100	108	6 days	39	29	Cm; NE; E	SW; NE; NW	1·5	0·02
Panjgur	99	108	26-v	58	50	W; E; NE	SW; SE	3·9	0·44
Pasni	91·5	98	15-v	72	87	E; W; NW	SW; W; S	0·5	0·44
Sibi	106·8	118	31-v	34	..	Cm; SW; S		1·9	0·55
June 1933.									
Seistan (Iran)	101·7	110	19-vi	41	28	NW; N	NW N; E	0·3	Nil
Nokkundi	111·1	118	19-vi	30	20	N; E; NW	N; NW; NE	0·6	Nil
Dalbandin	108·9	115	23-vi	33	23	NE; E; SE	NW; SW; N	0·2	Nil
Panjgur	105·8	111	18–22-vi	58	46	SW; Cm; W	N; SW; NW	0·4	0·02
Pasni	92·6	97	1-vi	74	84	E; W	SW; W; S	4·7	Nil
Sibi	113·5	119	22-vi	39	..	S; SW; SE	..	0·3	0.03
July 1933.									
Seistan (Iran)	106·4	112	25, 26-vii	36	26	NW; N	N; NW	0·3	Nil
Nokkundi	115·5	117	3-vii	31	16	N; NW; NE	NW ; N	1·6	Nil
Dalbandin	108·8	113	5 days	41	24	SW; W; S	SW; S	2·2	0·32
Panjgur	103·6	111	14, 15-vii	66	56	SW; NW; W	SW; N ;NW	3·2	0·02
Pasni	89·8	99	4-vii	81	85	E; SE; SW	SW; S; W	8·4	0·07
Sibi	108·3	119	3-vii	52	..	SE; S; Cm	..	2·1	1·06

From the above table, it may be seen that there was a gradual rise in the maximum temperature between April and July 1933, and in the interior of the country, air humidity gradually diminished. As a result of maritime influence, however, the humidity was relatively high at Panjgur and very high at Pasni. While the degree of humidity in the afternoons was lower in the interior, it was higher at Pasni on account of the prevalence of sea-breeze. The dominant direction of wind was north and north-west in the interior, but in Mekran it was south-west, especially in the afternoons. With the development of conditions of such high saturation deficiency, locusts produced in the interior of Baluchistan had presumably left these regions and migrated with the prevailing winds either into the coastal areas or north-eastwards into Sind or Kachhi, and thence into Rajputana.

Summer Breeding. In consequence of fairly widespread monsoon rainfall, breeding had apparently occurred in many parts of Rajputana, south Sind, south-west Punjab and south Baluchistan, but hoppers were reported only from Kech, Kolwa, Lasbela and the Dera Ghazi Khan district of the Punjab. In the desert areas of Sind and Rajputana, however, hoppers would appear to have been missed by the survey staff on account of their want of experience of the conditions of breeding in the desert though the collections made included numerous samples of recently fledged locusts.

Thar-Mallani Area. The first visit to this area was made between the 31 July and 23 August when a fairly dense population was met with. Most of the locusts collected were, on examination, found to have yellow or deep yellow wings, with a trace of pink or mauve at the base, and evidently represented the old generation—presumably migrants. A few collected during the third week of August, had, however, hyaline wings and were apparently a new generation. Since a fair amount of rainfall was recorded at the end of June at Barmer and during July at Chachro, these locusts were probably the result of the earliest egg-layings. The biometrical facies of the collection was:—50S:43T:7G: :87(6):13(7).

During tours carried out in the Bahawalpur area in August, a fairly good population was noted in parts of the State, especially at Derawar, where the density was about 300 per square mile. Out of a collection of about 50 specimens from the Bahawalpur area, the biometrical index proved to be:—64S:30T:6G: :83(6): 17(7). It was reported that many possessed a strikingly greenish-grey body coloration, and that a fair number had hyaline wings. During biometrical examination it was noted that the majority had yellow or bright yellow wings tinged with pink at the base, though in a certain number they were hyaline or light yellow. Presumably, the majority belonged to the old generation, specimens with light coloured wings representing the new brood.

Fairly good rainfall was received during the last week of June in the Rajputana desert, especially in south Marwar, and had apparently been followed by light concentrations of locusts and scattered breeding but in the Thar area, there had been no rain. July proved to be comparatively dry in Rajputana, and rainfall (one to two inches) was greatly in defect, so that conditions were unfavourable for oviposition. On the other hand, fairly heavy rain fell during the latter part of July in the Thar area of South Sind, and in the Karachi-Lasbela section. Very heavy rain was received in most parts of western Rajputana during August—varying from 5 inches at Barmer to 12 inches at Bikaner and 15 inches at Jodhpur, as a result of which heavy breeding would appear to have followed in September. The forms with hyaline wings found during August were apparently the outcome of eggs laid at the end of June or early in July.

Lasbela Area. During June and the early part of July, only small numbers were met with around the Ambagh Field Station, but after a

burst of rainfall amounting to 9·50 inches between the 16 and the 23rd July, quite a large number was observed on the field. As some of the female locusts collected at the time were fully mature, oviposition had apparently ensued almost immediately after the rains, seeing that adults of the new brood were noticed in the field by the middle of September.

Mekran area. At Pasni, summer rainfall amounted only to 0·67 inch received on the 17th July, and consequently there was no summer breeding, unlike 1932, though hoppers were being met with in the special rek areas, in small numbers, till the middle of September. Periodical surveys carried out on the Pasni reks, however, revealed a steady increase in the population during June and July, which could not be attributed to local multiplication. By August, however, their numbers had considerably diminished. In the Gwadar-Pishukan area, hoppers were present on the reks at the end of June, but were not observed during July.

As a result of rainfall (about 1·50 inch) in July in Kech, Panjgur and Kolwa, some light breeding had apparently occurred in the interior of Mekran, since hoppers were met with in small numbers in August at Taloi-Sunt on the Shadi Kaur and in September in Kolwa and Kech. During tours in June, in Kech, Dasht, Gwadar and Kulanch areas, a fairly high locust population was noticed in many localities. In July, the areas of Balgattar, Panjgur, Parom and Buleda were examined, when a high population was similarly met with. In the absence of requisite observations, it is not possible to say whether the locusts found in the Panjgur areas had been locally bred or had immigrated from outside. On the analogy, however, of the events of 1935 [Rao, 1936, 1937], it appears quite likely that, in view of the good rainfall during March, April and May at Turbat and Panjgur, fairly wide-spread breeding had occurred in these interior valleys during May-June as a result of an immigration of locusts from the coastal areas. It is also not unlikely that light concentrations of hoppers had been brought into existence in this area, but were not recognized by the survey staff for lack of experience. It is particularly unfortunate that a collection of locusts made at the time in these areas had not been preserved, as a biometrical examination might have furnished valuable clues on the character of the breeding.

It is interesting to note, in this connection, that presumably as a result of breeding induced by the good spring rainfall, *Locusta migratoria*, ph. *solitaria* was found in large numbers in many of the interior valleys, during July 1933, along with *Schistocerca*.

In the course of tours carried out in August in Kech, Kulanch and Ormara areas, the density of population was found to have considerably decreased. During a visit to Kachhi in August, Bhatia did not find any locusts, though good rainfall had occurred.

IV. Autumn Period 1933, *Sind-Rajputana Desert Area.* In September Baweja examined various localities in the desert areas of Bahawalpur and found a fairly high locust population, especially at Dunga-Bunga (1-4 September), where the density was computed to be about 500 to 600 per square mile. Fair numbers were also found in the Bikaner area (Bikaner, Sardarshahr, Suratgarh and Pugal). Several locusts were similarly noticed in the Khairpur State during his visit in the middle of September. In the eastern part of Mallani in early September also locusts were found fairly common. A biometrical analysis of the collections showed that the population was mainly composed of a recently developed generation, though fair numbers of the old brood (with deep yellow wings and sometimes with pinkish bases) were also noticeable till the middle of the month. Out of a collection of 68 individuals, the biometrical index was found to be 74S:22T:OG::75(6):25(7).

In October during a tour in the Thar area, locusts were noticed in fair numbers throughout the desert, the density varying from 100 to 400 per square mile. A collection of 56 specimens from this area was, found to denote the following facies:—75S:22T:2G::33(6):67(7). Most of the specimens had hyaline wings and were doubtless recently fledged. A certain proportion, however, had yellow wings, indicating sexual maturity. A few were also found to have greenish body coloration. In the western parts of Sind fair numbers of locusts were observed at places, the density varying from 50 to 250 per square mile.

Between the 4th and the 22nd October, the long strip of country lying between the Indus and the Sulaiman Range from Dera Ismail Khan in the N. W. Frontier Province down to Mithankot in the Dera Ghazi Khan district of the Punjab was examined and numerous sandy patches were discovered in this sub-montane area, suitable for locust breeding. Solitary adults were located in some places, especially at Tibbi Kasrani and Dera Ghazi Khan, the population density being about 200 per square mile. At Sakhi Sarwar near Dera Ghazi Khan, a sandy area with bush vegetation was discovered, in which about 54 green hoppers of the Desert Locust (instars II to V) were found mostly on *Aerua tomentosa* (*javanica*). The batch of hoppers observed may be deemed to be the tail end of breeding set on foot by heavy rainfall in August-September. The adult locusts found in this area were mostly *solitaria*. In the Bikaner area the presence of a good number of locusts was reported during October, especially in the high-dune areas of Pugal, Badrasar and Barsilpur.

In November, Bhatia traversed the desert from Khipro to Jaisalmer, *via* Ranahu, Mankahu, Mayajlar and Kuri, and found only one locust near Kuri. Returning early in December, from Jaisalmer *via* Sheo and Barmer he observed very few locusts at these places, so that it was apparent that the bulk of the population had already migrated.

During the latter part of November, the north-eastern parts of Jaisalmer, from Phalodi to Jaisalmer, *via* Nokh, Baru and Sodakhor, were examined a high population of solitaries was found at many places, the density varying from 400 to 2,000. In the area around Jaisalmer—which forms a rocky plateau in the midst of the sandy desert—no locusts were seen, but northwards from Jaisalmer to Khanpur, again, fairly large concentrations were encountered in the high dune areas of Sultana (Dawar), Bhutanwala and Islamgarh, in the first week of December.

A collection of 132 specimens from the east Jaisalmer area—between Phalodi and Jaisalmer—pertaining to the latter part of November, gave the following analysis:—68S:T:2G: :38(6):62(7). Most of them had hyaline or light yellow wings, indicating recent fledging. Collections made in the first week of December between Jaisalmer and Islamgarh were found to have the following facies—88S:10T:2G: :21(6):79(7). It is apparent that these two lots belong to a more or less homogeneous stock, showing a preponderance of *solitaria* ratios and 7-striped forms.

While examining parts of the Khairpur State and the Sukkur district along the western fringe of the Jaisalmer desert, fair numbers of locusts were found at the end of November and the beginning of December, the density varying from 50 to 100 per square mile.

From the above notes, it is seen that a dense population of locusts was observed in the northern parts of the Indian Desert during November and December, while in the southern parts they were relatively less numerous. Presumably, this circumstance will have to be correlated with the much heavier rainfall received in the northern parts (as at Bikaner, Sardarshahr and Bap) than in the southern desert (*e.g.* at Barmer and Chachro) during the month of August. With the June-July rainfall, a batch of breeding had probably occurred in the desert areas, the breeding being

heavier in the south than in the north; but after the heavy falls of August, denser breeding had probably taken place in the northern parts than in the southern, where it was apparently light in view of the lower rainfall.

As to the oviposition that had occurred subsequent to the heavy rains of August, part of it ought, doubtless, to be referred to the activities of the old generation of locusts, which were known to be still present in the desert at the time. As adults of the new brood had begun to appear in numbers in August, it is not unlikely that many of them had become sexually mature by the end of August or the beginning of September and had themselves laid eggs, starting thus the second generation of the monsoon. The brood of hoppers, observed in September and October, whether referable to parents of the old (spring) generation or to those of the new (monsoon) brood were apparently able to develop into adults only by the end of October or the beginning of November. A similar occurrence was noticed in the monsoon period of 1936 in the desert areas. It is quite likely that in 1933, as actually observed in 1936, all adult locusts whether of the old or the new brood, as were present in these areas in September-October, had, under the influence of conditions of high saturation deficiency that developed at the time, migrated out of the desert, whereas those produced by the end of October or during November, when such conditions had disappeared owing to the advent of the cold weather, had apparently not felt the same urge to leave the area.

Monthly Meteorological Data for August—December 1933 in West Rajputana

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rainfall
	Mean maximum in Degrees F	Highest maximum in Degrees F	Date	8 A.M.	5 P.M.	8 A.M.	5 P.M.		
				Percent	Percent	Percent	Percent		Inches
August 1933									
Bikaner .	90·5	98	5-viii	83	65	SW; S	SW; S; NE	6·2	11·62
Jodhpur .	87·4	97	1-viii	86	74	SW; Cm; W	SW; S; W	9·4	15·19
Barmer .	87·5	95	1, 8-viii	84	68	SW; W; Cm	SW; S; W	7·5	4·93
September 1933									
Bikaner .	94·0	100	8, 9-ix	67	45	SW; W; NE	NE; SW; NW	2·1	0·25
Jodhpur .	92·2	98	13, 14-ix	74	49	SW; NE; E	SW; NE; N	4·8	1·61
Barmer .	92·8	98	18-ix	72	44	W; NW; S; Cm	NE; SE; Cm	3·5	0·72
October 1933									
Bikaner	94·1	100	12-x	42	21	SW; S; W; NE	W; SW; NW	0·5	Nil
Jodhpur .	95·9	101	10, 12-x	50	23	Cm; NE; SW	SW; Cm; NE	1·2	0·13
Barmer .	Not	recorded		49	28	Cm; W; NW	W; Cm; NE; SW	0·7	0·12
November 1933									
Bikaner .	86·5	94	1-xi	33	13	SE; E; S	W; NE; N; SE	0·9	Nil
Jodhpur .	89·4	96	1-xi	40	20	NE; Cm; N; E;	NE; Cm; N	1·7	Nil
Barmer .	Not	recorded		51	38	NW; Cm; N	NE; Cm; W	1·1	Nil
December 1933									
Bikaner .	77·8	87	3-xii	58	26	SE; E; S	W; N; NE	1·4	Nil
Jodhpur .	80·7	86	3, 4 xii	53	27	NE; Cm; N	Cm.; NE: SW	1·0	Nil
Barmer .	80·7	89	3-xii	65	40	NW; Cm; N	Cm; NW; NE	0.9	Nil

In the above table, the rise of temperature, the fall in humidity and the brighter skies prevalent in September and October are note-worthy. In November, the conditions were similar except for the fall in temperature, while in December, a further fall is observable as well as a rise of humidity in the mornings. The dominant wind direction is northerly, north-easterly or north-westerly from October onwards.

Lasbela Area. Green hoppers were being found all over the reks during the month. Breeding was observed also at Goth Sherkhan, and at Liari, Bannodi, Nakhetri and Khandewari, where quite large numbers of hoppers were noticed. In view of a record of 2·20 inches in August and of 1·70 inches in September at Ambagh, conditions were apparently favourable for the continuance of breeding in the Lasbela area. No breeding was, however, noticeable in the Hingol area between Pohr and Hingol. At Ambagh, hoppers were being found till the third week of October. Adult locusts of the new generation were first met with during September, many of the fresh adults being noticed to be pinkish in colour.

Fairly good numbers of pink locusts were being met with throughout October and were noticed till the middle of November. Preserved samples of such pink individuals were found to possess mostly *solitaria* ratios, and pinkish hind-wings. It was noticed that when confined in cages and kept under semi-natural conditions in the sun, they gradually lost their pink colour and assumed the grey-brown stripes characteristic of solitary locusts. Since similar pink-coloured locust individuals were met with in the course of autumn migrations in 1936 and 1937 in the Lasbela area, it is presumed that the pink colour might be connected with autumnal migration from the east.

Out of 28 specimens collected in September, all except one were either *solitaria* or *transiens*, and leaving out of account 9 specimens in which eye-stripes were not clear, the majority had six stripes. The biometrical index proved to be: 53S:43T:4G: :84(6):16(7). Out of 31 specimens collected in October and November at Ambagh, 21 were *solitaria* and 10 *transiens*, and most were seven-striped. The facies was found to be 68S:32T:OG: : 6(6):94(7).

Calculations of population density in the Ambagh area indicated an average of 147 per square mile for September, 686 for October, 1,228 for November and 983 for December. While the increase seen in October might be attributed to local breeding, the high figures for November should be due, presumably, to immigration from outside.

Mekran Area. At Pasni, the population was found to have considerably decreased by the end of September, and by the middle of October very few were noticeable. Between the 12th and the 24th October, the dry north-east wind—the 'Gorich'—was prevalent at Pasni. From the 26th onwards, fair numbers of locusts were met with on the reks during surveys. A fairly high population was noted during November and December, and presumably the rise of density was due to autumn migration from the east. Unfortunately, specimens of this period have not been preserved, but one form collected, on the 15th December 1933 at Pidarak (on the route between Pasni and Turbat) had bright pink wings and an E/F ratio of 2·05. A record in the Pasni Survey register as to the find of red mites on the wings of a locust collected on the 30th October is also corroborative evidence of migration. Ormara was visited in October when the density of population was about 152 per square mile. At Gwadar a fairly high density was noted during the autumn months, but a decrease of population was noticeable during November and December.

In Kolwa, several specimens of green hoppers as well as a few newly emerged adults were found early in September; and in Kech, a V-stage

hopper and several new adults, by end of September and beginning of October. Few locusts were found in Kech and Kulanch during November, but by December an increase in number was noticeable presumably due to immigration.

Locust movements reported during 1933-34.

A few reports of swarm movements were received from different sources by the Central Locust Bureau, Delhi in 1933 and 1934, and information about similar other movements was collected by the survey staff during their tours. The available data are as below arranged chronologically:—

1. 9 *October* 1933. A swarm was reported by the Punjab Agricultural Department to have passed over fields near Arafwala in Montgomery district. It was said to have appeared from the direction of the Bahawalpur State and to have returned in the same direction.

2. 14 *October* 1933. A swarm was reported by the Collector of Muttra, United Provinces, to have come flying from the Punjab and to have passed over Chhatta Tahsil towards Bhurtpur State.

3. *Mid-October* 1933. A loose swarm, 3 to 5 miles long, said to have been seen coming from the north-east at Sri Bejoynagar and to have moved towards Anupgarh; *Capparis* bushes were found damaged in this area.

4. *October* 1933. A light swarm was reported to have appeared at Fort Marot in Bahawalpur State and to have flown away after damaging *Capparis* bushes.

5. 27 *October* 1933. A swarm was reported by the Collector, Muttra to have passed over Muttra Tahsil on the 27th from Bhurtpur State and to have returned in the same direction.

6. *November* 1933. A small swarm was reported by one of the Field Kanungos of the Bahawalpur State along the borders of the Jaisalmer State at the beginning of the month.

7. *November* 1933. A swarm 2 miles long and two miles broad was said to have been seen at the beginning of the month, at mid-day, flying very high in a north to south direction, over Mohangarh in Jaisalmer State.

8. *November* 1933.—*2nd week*. A report was received from the Kotah State to the effect that yellow and pink locusts were found flying over village Suket in the second week.

9. *November* 1933. Assistant Mr. Bhatia had reports from the local inhabitants that light swarms had been flying along the coast of Cutch from east to west.

10. 1 *January* 1934. Commissioner, Nimar Division, Indore State reports that locust swarms had appeared at village Seona, Bhicangaon tahsil, Nimar district on the night of 1st January.

11. 26 *February* 1934. The Western India States Agency reported that a swarm of locusts appeared on the 26th February at Jhotana, Katosan taluka, Sabar Kantha Agency flying from east to west, without alighting on the ground.

With reference to these swarms, it should be mentioned that none of the official reports were accompanied by specimens of locusts, and in the case of the reports from Muttra, the Muttra and Bhurtpur areas were visited early in November but no locust specimens were met with. As to the swarms reported by local people in Bikaner, Jaisalmer and Bahawalpur, Mr. Baweja was shown the extensive damage done to the bark of the Leafless Caper (*Capparis aphylla*) in several places, so that there is little

STATEMENT III

Results of Locust Surveys—1933

(The figures represent the average population per square mile for the whole month in the areas surveyed and 'H' represents occurrence of breeding)

Season	Months	BALUCHISTAN										SIND-RAJPUTANA DESERT						
		MEKRAN						LASBELA										
		Gwadar-Pishukan	Pasni Reks (Int. surveys)	Ormara	Kech Valley (including Shadi-Kaur valley)	Kulanch Dasht	Kolwa	Panjgur Area	Hingol	Ambagh Reks (Int. surveys)	Hinidan Bela	W. Sind & Kachhi	S. W. Punjab Bahawalpur	Thar Mallani	E. Jaisalmer W. Bikaner	Kathiawar	E. Bikaner	E. Rajputana
Winter	Dec. 1932		207							400							27	
	Jan. 1933	6	463			30			400	320	120							
	Feb. 1933		132							230								Nil
Spring	March 1933	Nil	H 27										30			3		
	April 1933		H 126		H100(?)	H Nil				100		4						
	May 1933	H100(?)	H 546	H 333	240	H 290	891			20		3						
Summer	June 1933	H 193	H 506		555	260	840			34		23	13					
	July 1933	332	H 686			94		913		140		9	Nil	48	59		184	
	Aug. 1933	785	H. 299	158	210	336	Nil			H 166		Nil	H 93	H 148	3			
Autumn	Sep. 1933	803	H 171		H 110		H 14		H 1900	H 147		Nil	143	H 38	H 21			
	Oct. 1933	920	189	152		23			H 2100	H 686		53	H 56	113	H 68			
	Nov. 1933	465	212			24		40		1228			29	13	454			

doubt that the locust movements reported were not mere figments of the imagination.

Taking into account the fact that very heavy rain had fallen early in August in the Bikaner area and in the adjoining Bahawalpur and Jaisalmer territory, heavy breeding had presumably been set on foot soon after, leading to the appearance of quite a large population of solitary locusts by the end of September and the beginning of October. As by that time conditions of high saturation deficiency had developed in the Bikaner area, it is possible that the majority of the adults had begun to feel the urge for leaving the area, and it is not unlikely that a simultaneous movement of individuals had given the semblance of small loose swarms. A similar occurrence was actually noted in the Bikaner area in August 1937. As by the end of September much of the desert vegetation usually begins to dry up, it is possible that large numbers of locust adults might have concentrated for feeding on patches of *Capparis* bushes common in desert depressions, and thus, assumed the semblance of small swarms.

The general direction of movements recorded in the above data coincides rather closely with the trend of flights noted in respect of swarms reported in these areas during periods of mass multiplication and this circumstance gives support to the view that these movements had been based on facts.

Summary of events in 1933.

The following were the main developments in the activities of the solitary locust in the Indian area during 1933: (1) The fall of heavy, though late, winter rains in Baluchistan leading to the development of breeding, both along the coast and in the interior of Mekran between March and June, (2) the appearance of good numbers of locusts, mostly with *solitaria* and *transiens* ratios, in Sind-Rajputana areas in June-July, presumably from the west, (3) extensive breeding in many parts of the desert in July-August, due to early rainfall by end of June, (4) the continuation of breeding up to the end of October in the northern parts of the desert, as a result of heavy rainfall in August, (5) light breeding in summer in the Kech and Kolwa valleys, and heavy breeding in the Lasbela area and (6) reports of occurrence of light swarms in the Rajputana area in the autumn months. While, in general, forms with 6-eyestripes predominated during the earlier part of the year, it was noteworthy that by the end of 1933, the locust population was mostly composed of 7-stripped forms.

Year 1934

Weather notes for 1934.

Winter rainfall 1933-34. About fifty western disturbances were recorded between October 1933 and the first week of June 1934 in Baluchistan and North-West India. Very few of them, however, resulted in rainfall of any consequence. In January, there was a severe cold wave between the 10th and the 24th in the rear of a disturbance, and a second one occurred at the end of the month. In March, some rainfall occurred in the interior of Baluchistan, and fairly heavy rain (4·29 inches) fell at Jask and about an inch or two at Henjam in Iran, and at Muscat. Bahrein and Sharjah in eastern Arabia, but in the rek areas of British Baluchistan, there was a failure of rain.

In the desert areas of Rajputana also, there was little rainfall, except in east Bikaner where an inch or two was recorded at Nohar and Anupgarh in March, while Hissar (at the eastern fringe of the desert) received 4·24 inches at that time.

Monthly rainfall data for Winter-Spring 1933-34

Localities	Dec. '33	Jan. '34	February '34	March '34	April '34	May '34
Iran.						
Jask . . .	..	0·66	..	4·29	0·19	..
Henjam . .	0·18	0·38	..	1·40	0·14	..
East Arabia.						
Bahrein . .	..	..	0·03	1·74	0·28	..
Sharja . . .	..	0·41	..	1·88	..	..
Muscat . .	..	0·42	..	1·15	..	..
Baluchistan.						
Pasni . . .	0·03	0·63	..	..	..	..
Gwadar . .	..	..	..	0·06	..	..
Ormara . .	..	0·09	..	..	..	..
Turbat . .	0·30	0·20	..	..	..	..
Panjgur . .	..	0·22	..	0·22	0·25	..
Gandhawa . .	..	..	..	0·32	0·13	0·14
Quetta . :	0·27	0·84	0·12	1·08	0·38	0·16

Monsoon rainfall 1934.

Fairly high day temperatures prevailed in northern India in the latter part of May and the first fortnight of June. The monsoon established itself in Malabar only on the 8th. A low pressure area developing along the west coast and moving northward towards the seasonal low of northwest India by the 26th, brought about a rather early extension of the monsoon into Northwest India. Good rainfall continued during the first week of July, but the rest of the month was dry. In August under the influence of four different depressions from the Bay, fairly heavy showers were received in western Rajputana, but in Sind and Baluchistan, the

rainfall was, on the whole, light. There was little rainfall in September, the monsoon withdrawing from North-West India by the 15th.

Monthly rainfall data for the monsoon period 1934

Localities	May	June	July	August	September
Rajputana Area.					
Bikaner	0·40	1·93	1·79	11·51	0·55
Sardarshahr	..	1·27	0·90	6·58	0·34
Jaisalmer	0·81	0·52	1·35	2·42	..
Bap	..	1·20	0·60	15·82	..
Jodhpur	0·01	4·34	0·88	9·28	0·46
Barmer	0·84	0·84	1·91	6·94	..
Sind Area.					
Chachre	..	2·10	1·98	3·46	0·01
Karachi	..	1·28	6·49	0·23	..
Jacobabad	..	2·47	2·11	1·00	..
South Punjab.					
Hissar	0·02	2·20	2·75	5·80	..
Khanpur	0·05	2·02	0·32	2·66	..
Baluchistan Area.					
Gandhawa	0·14	1·69	0·36	0·23	..
Sibi	0·05	1·97	1·58	1·44	..
Bela	..	1·61	1·28	2·60	0·31
Ambagh	..	2·16	1·10	0·97	..
Ormara	..	0·24	..	..	..
Pasni	..	0·43	..	0·02	..
Panjgur	..	0·51	..	1·18	..
Turbat	..	1·08	0·34	0·21	..

Observations on Locust Distribution during 1934
(*Vide* Statement IV)

I. *Winter period* 1933-34. *Mekran.* A fairly dense population was noted in the rek areas during winter months, especially at Pasni and Gwadar, but in the interior only small numbers were found during this period in Kulanch and in the Dasht and Kech valleys.

Lasbela. A fairly high population (average density about 1,000 per square miles) was noted on the Ambagh reks during December, 1933 (see Statement III), but the population greatly diminished during January and February. Specimens collected between January and March at Ambagh were found to have either pinkish or purplish hind-wings in the majority

of cases, and out of 20 samples preserved, 13 were *solitaria* and 7 *transiens*. The biometrical index was 65S: 35T: OG: :27(6):73(7). Presumably they were all over-wintering forms, and it is possible, that, whenever there were spells of warm weather during winter, migration was in progress. In four cases, green algae were found on the hind-wings.

Sind and Kachhi. In February, no locusts were found in the Kachhi area, nor any in the desert area east of Rohri, or in western Sind, except for a single locust at Larkana in January.

The Sind-Rajputana Desert Area. Fairly high concentrations were observed in December 1933 on the Jaisalmer-Bahawalpur borders. None were found elsewhere in December and January, but in February a few were noticed near Rahim Yarkhan and Ahmadpur East. Small concentrations were noted in parts of Bikaner in January, and in February-March in the high-dune areas such as Suratgarh, Anupgarh, Rojri, Pugal, Bikampur and Nachna. The density was of the order of 100 to 300 per square mile. In the southern parts of the desert, few locusts were to be seen, though in eastern Mallani and the neighbouring Jalor-Bhinmal area of Marwar some scattered specimens were met with among fields of wheat and rape-seed in January-February.

On the whole, the data available would indicate that the bulk of the locust population was massed in the rek areas of Mekran and Lasbela, though a certain number of them were observable also in the northern parts of the Rajputana desert, where they were apparently over-wintering.

II. *Spring Period*, 1934. *Mekran and Lasbela*. The salient feature of the spring period of 1934 was the almost complete failure of winter and spring rains in both the coastal and interior areas of Mekran and Lasbela. This was associated with a complete absence of breeding of the solitary phase locust in these areas.

Nevertheless, a fairly high locust population was met with in the rek areas of Gwadar, Pasni, Ormara and Ambagh during the spring period. In the Ambagh area, however, the average density for March was about 360 per square mile, but in April and May it was only 37 and 89 respectively. On the other hand, the average density for March, April and May respectively was 79, 114 and 46 on the Pasni Reks and 455, 507 and 520 on the Gwadar-Pishukan Reks. During surveys carried out in the Ormara area in April, the average density was found to be about 57. These figures are rather suggestive of a progressive increase of locust population taking place from east to west with the advance of spring (*vide* statement IV).

Considering the fact that there was fairly heavy rainfall in March at Jask on the Iran coast, and also a fair amount in the Muscat-Oman area of east Arabia in February and March, it is possible that a part of the locust concentrations known to have been present in winter in Mekran and Lasbela reached the Jask and Oman areas during the spring months and bred there.

A small collection of 8 locusts made in April on the Mekran reks showed the index: 75S: 25T: OG: :50(6): 50(7).

In the interior of Mekran, small numbers of locusts were observed in March in the Kech valley at Sami and in the Panjgur, Parom and Buleda areas and in April, none were found except for two near Awaran in Kolwa on the 24th April. A fairly good number was observed in May in the Kulanch-Dasht area, and two specimens at Liari in Lasbela in May.

Sind-Rajputana area. In western Sind, small numbers were found on *Capparis* bushes and among cultivation in April, especially at Tharri and Mirzapur. None were found in the Khairpur areas between March and May, and in the Bahawalpur area only a stray locust or two. In the Bikaner area a few were met with in April, and a comparatively larger number in May, especially near Badrasar and Napasar. An examination of the collection showed that they belonged to the old over-wintered generation. In the Thar-Mallani area, no locusts were met with in the course of an extensive tour in March-April, the first specimen of the season being collected at Chachro on the 19th May. During a visit to the Cutch State in May, Bhatia found three locusts in the low sand-dune area along the coast near Mandvi, as well as a single specimen of the Bombay Locust (*Patanga succincta*). A few specimens of *Locusta migratoria* ph. *solitaria* were also found in cultivated fields at Bhuj and Mandvi. No locusts were seen elsewhere.

III. Summer Period, 1934.

Summer migration. A. *Mekran-Lasbela Area.* In spite of an absence of breeding, a slight, though perceptible, rise of population was noticed during the second fortnight of May at Pasni, as also simultaneously on the Ambagh reks. At the same time, a change in its biometrical characteristics was noticeable. It was found that the collection made in April, 1934, on the Mekran reks, had the index: 75S:25T:OG: :50(6):50(7) and the one pertaining to the Lasbela area prior to May :65S : 35T : OG : :27(6): 73(7). On the other hand, 10 specimens collected in the Mekran rek area between May and August had the index: 40S:40T:20G: :90(6):10(7) and a similar collection at Ambagh, the facies: 36S:64T:OG: :56(6):44(7). In both cases a similar relative fall in the relative proportion of *solitaria* forms and a rise in that of the 6-striped ones is noticeable. Most of the forms found in May and June showed hyaline or light yellow wings, with traces of pink or mauve at wing-bases, except for two from the Lasbela area which had brownish yellow wings and carried green algae, evidently over-wintered forms. It is presumed that the majority were a recently developed generation of extraneous origin. Three specimens collected in July at Pasni and on the Pishukan reks had specially high ratios (2·11, 2·20 and 2·30) and presented an appearance similar to that of the migrants observed at Pasni in June 1932 and later on in July 1935. As several migrants of a recent generation were also noticed in the Sind-Rajputana deserts in June-July 1934, it is considered likely that all these had originated from a western breeding ground—possibly Jask and Oman areas, since very little winter rain had been received elsewher in 1934.

B. *Sind-Rajputana Area.* As already noted, over-wintering locusts were present in Bikaner and Jaisalmer in small numbers during the winter period and a biometrical analysis of 19 specimens collected between January and March 1934 gave the following index: 53S:47T:OG: :42(6): 58(7). Most of them possessed transparent, or yellowish wings and green algae were seen on the wings in a few cases.

As already stated, fair numbers were met with during May near Badrasar, Surasar and Napasar and around Bikaner. In the latter half of May and during June, fairly good concentrations were met with at various localities especially at Nokh (38 locusts seen 19-21 June), Phalodi, Baru and Rojri, the density ranging from 100 to 600 per square mile. (There is reason to believe that the concentrations of locusts noted at Nokh and Phalodi at this period had been caused by the action of winds accompanying rain-storms, especially as a heavy downpour of thunder-storm rain had occurred on the 18th at Phalodi). A collection of 52 locusts from these areas showed the index: 84S:16T:OG: :33(6):67(7). Except for 8 specimens, which had light yellow wings with a tinge of blue at the base the majority had deep or smoky yellow wings with fairly abundant growths of green algae in many cases.

Evidently, most of these locusts belonged to the late brood produced in these areas during October and November 1933 and had probably over-wintered in the desert. It is possible, however, that a good part of these had migrated westwards in the early part of spring, possibly up to Kachhi. Under similar conditions in 1937, a migration of locusts into Lasbela and Kachhi was observed, as also extensive breeding in Kachhi and Bolan as a result of spring rainfall. In 1934, however, there was no possibility of breeding in view of the drought, and it may be presumed that with the development of south-west winds in May they had re-migrated eastwards into Jaisalmer and west Bikaner.

With the fall of fairly good rains in the latter half of June and the first week of July, it is probable that oviposition had ensued in these areas. The rest of July, however, proved to be dry, and except for 3 specimens collected at Sardarshahr in the first week, no locusts were met with in these areas.

In August, heavy rains were received in many places in the Rajputana desert, and good numbers of locusts were met with in such areas especially at Rojri and Derawar. A collection of about 30 locusts had the following index: 86S:14T:0G: :40(6):60(7). Some of these had hyaline or light yellow wings and were evidently recently developed, while others had deep yellow or brownish yellow wings. None of the latter, however, had green algae on their wings, except in the case of a specimen collected on the 5th August at Rojri, so that it is evident that the over-wintered generation marked by algal growths had mostly disappeared by August, and that the bulk of the individuals with the deep yellow wings were summer migrants from the west.

In the southern desert areas, over-wintering did not occur, and the first locust of the season was observed at Chachro on the 19th May, and further specimens in June after monsoon rainfall; and some more were met with in July. Of these, none except the one collected on the 19th May and another on the 23rd June carried green algae. An analysis of the small collection made at this period indicated the facies 69S:23T: 8G: :54(6):46(7). It is probable that the locusts found in June-July in Thar were mostly migrants from the west.

The following are the meteorological data for the western areas for April-July extracted from the Monthly Weather Data, 1934, of the India Meteorological Department, related with factors affecting the migration of locusts from the western areas in summer.

Monthly Meteorological Data for the Period April-July, 1934 for Baluchistan Areas

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud amount	Rain-fall
	Mean Maximum Degree F.	Highest Maximum Degree F.	Date	8 A.M.	5 P.M.	8 A.M.	5 P.M.		
				Percent					Inches
April 1934.									
Seistan (Iran)	87·7	98	15-iv	61	37	N; NW	N; Cm; NW	1·5	3·03
Nokkundi .	90·2	100	6-iv	68	70	NE; E; N	NW; N; NW	4·3	Nil
Dalbadin .	88·9	97	6-iv	30	9	NE; Cm; E.	SW; SE; S.	3·6	0·20
Panjgur .	89·9	98	5-iv	54	48	NE; E; NW	SW; N; NE	2·2	0·20
Iask (Iran) .	87·3	93	17—21-iv	67	65	NW; W; N	W; NW	3·1	0·19
Pasni . .	95·1	104	7—19-iv	54	67	W; NW; SW	SW; W	2·8	Nil
Sibi . .	99·8	107	8-iv	18	..	Cm; NW; NE	..	3·6	0·92
May 1934.									
Seistan .	91·4	100	25, 31-v	54	34	N; NW	N; NW; NE	1·9	Nil
Nokkundi .	97·5	107	26-v	59	59	N; NW; E	NW; N	2·4	Nil
Dalbandin .	96·1	106	31-v	25	9	NE; E	SW; W	1·6	Nil
Panjgur .	96·9	106	31-v	57	52	NE; SW; W	SW; N; NE	0·4	Nil
Pasni . .	93·7	104	23-v	68	74	W; SW; E	SW; W	1·0	Nil
Jask .	92·0	97	17-v	68	62	W; E; NW	W; S; NW	1·0	Nil
Sibi . .	106·1	115	26, 27-v	23	..	CM; NW; NE	..	2·4	0·05
June 1934.									
Siestan .	102·8	107	8 days	45	32	NW; N	NW; N	0·4	Nil
Nokkundi .	109·8	117	23-vi	57	44	N; NW; E	NW; N	1·3	Nil
Dalbandin .	107·8	115	23, 24-vi	22	9	SW; NE; E	S; SW; NW	1·1	Nil
Panjgur .	105·4	113	22-vi	55	46	SW; Cm. N	N; NW; SW	1·9	0·51
Jask (Iran) .	97·1	103	4 days	70	67	E; Cm; W	W; SW; S	8·2	Nil
Pasni . .	93·0	97	20-vi	74	80	SW; SE; W	SW; S; W	5·8	0·43
Sibi . .	111·6	121	15-vi	30	..	Cm; SE; S	..	1·5	1·97
July 1934.									
Seistan (Iran)	103·0	107	5 days	34	23	NW; N	NW; E	0·5	Nil
Nokkundi .	109·7	117	30-vii	54	44	N; NW; E	N; NW	1·8	Nil
Dalbandin .	108·7	112	4 days	20	8	SW; W; Cm	SW; S; NW	0·7	0·23
Panjgur .	104·2	108	4 days	67	42	SW; N; NW	NW; SW; N	2·7	Nil
Jask (Iran) .	96·5	102	14-vii	79	66	E; SE	S; SE	5·0	Nil
Pasni . .	92·0	97	6, 7-vii	72	66	W; SW; S	SW; S; W	7·9	Nil
Sibi . .	105·0	108	4 days	60	..	S; SW; SE	..	0·7	1·58

The above data, would show that the development of conditions of heat and drought had apparently commenced as early as April in the interior and that even at Pasni unusually high temperatures prevailed in April and May, presumably due to failure of rainfall. On the other hand, conditions were apparently normal at Jask as good rains had fallen there.

(2) *Summer breeding. Mekran area.* As rainfall was deficient on the coastal areas in summer, no summer breeding was noticed anywhere. In the interior of Mekran, on the contrary, the influence of the monsoon was felt in the Kolwa, Kech and Panjgur valleys, Turbat recording 1·08 in., 0·34 in. and 0·21 in. in June, July and August respectively, and Panjgur, 0·51 in. and 1·18 in. in June and August. Though no locusts had been found in May in the Kech-Panjgur areas, fair numbers of individuals were noted in July around Turbat as well as in Kolwa (at Rodkan, Goshanak and Awaran), and in the first fortnight of August in the Panjgur-Buleda areas. Although no mention had been made in reports about the existence of hoppers, there is little doubt that light breeding had occurred. It is also not improbable that the entry of locusts in July and August in these areas had been brought about by the agency of storms connected with monsoon rain, as was actually observed to have happened later on in 1937. As none of the locusts collected were preserved, nothing can be said of their phase characteristics.

Lasbela Area. At Ambagh station, rains commenced on the 26th June and by the end of the month, 2·16 inches were recorded. Further rainfall during the first week of July amounted to 1·10 inch; 0·97 inch was recorded towards the middle of August, the total fall being only 4·23 inches as against 13·40 in. recorded in 1933. Oviposition appears to have taken place immediately after the first rain at end of June, and hoppers were noticeable by the latter half of July. The first adult of the new generation was collected on the 15th August. No hoppers were found in September. Breeding was apparently confined to the Ambagh-Sonmiani reks, as hoppers were not seen either in the Hingol or the Bela areas. Compared with the previous two years, the breeding was very moderate.

North Rajputana Area. In Bikaner and north-eastern Jaisalmer, the monsoon caused fairly widespread rainfall between the 25th June and the 5th July, and conditions were favourable for locust oviposition. As there were fairly high concentrations of over-wintered forms in these areas, and breeding commenced soon after rainfall. During a period of about 4 weeks' dry weather that followed, conditions apparently did not permit of egg-laying, and few locusts were noticeable in these areas. During August, however, heavy rainfall occurred in many localities, and the survey staff found a good number of locusts all over the area in August. The population (which varied in density from 50 to 600 per square mile at different places), however, consisted (as stated earlier) in great part of forms with bright yellow wings, but without algae growths—presumably representing summer migrants from the west. There were in addition, however, numerous individuals with transparent wings, evidently the progeny of the over-wintered generation noticed in June. Hoppers were not met with in September and few adults were to be seen in these areas thereafter.

Thar-Mallani Area. In the southern areas of the desert, small numbers began to appear in May-June, and with the fall of wide-spread showers at the end of June and the beginning of July, light breeding would appear to have been set on foot. Hoppers were first met with at the end of July and were noticeable throughout August in the vicinity of Chachro, as well as also in many other parts of the Thar desert. One fresh adult was found on the 31st July at Dhakla. At Chachro itself the first adult of the new generation was collected on the 5th August, and in the course of the month the new brood was found gradually replacing the old generation.

Though most of the locusts found near Chachro were of the usual grey-brown colour with prominent buff and brown stripes, the discovery at Chachro, during August, also of several bright yellow forms was reported. A heavy wind-storm coming from the south-east had occurred on the

morning of the 12th August, followed by 1·25 inch rainfall. As the yellow forms were noticed in the wake of this storm, it is conjectured that they had been conveyed there from outside by the agency of wind. Altogether, thirteen specimens were noted, of which only ten were preserved. Biometrical examination showed that most of them had *solitaria* ratios and six eye-stripes, and were mostly males. Though with the data available, no definite statement can be made of their origin, it is not improbable that they represented the last batches of arrivals from the west. Usually bright yellow body coloration is characteristic of *gregaria* or *transiens* ratios, and the significance of its association, in the present case, with *solitaria* forms cannot be properly assessed in the present state of our knowledge.

31 preserved specimens of this period had the index: 79S:21T:0G:: 68(6):32(7).

IV. Autumn period, 1934. Thar-Mallani area. Only one hopper (IV-instar) was met with at Chachro during September, and two (one IV-stage and one V-stage) hoppers in October, so that in spite of rainfall in August, little breeding had resulted. At Chachro, fair numbers of adults almost entirely of the new generation, were found in September, the average density for the month being about 91 per square mile. There was a slight rise in October (about 115 per square mile), probably due to autumn immigration, since there was apparently little of local multiplication. By November, the population had dwindled down to 29 per square mile, while in December no locusts were to be seen at Chachro, or anywhere in the Thar-Mallani area. During autumn, the situation at Chachro was found to be typical for the whole of Thar-Mallani area.

During a visit to Ranahu, Mayajlar, Lakha, and Sheo in south Jaisalmer in the latter part of September, small numbers of a recently developed generation were met with all over the area, indicating the occurrence of general breeding. In October, a few locusts were met with at Sorah and Kot Diji in the Khairpur area, but by December, no locusts were observable anywhere in the southern desert areas.

Northern Desert areas. Although fair numbers were noted in parts of Bikaner, Jaisalmer and Bahawalpur in August, including individuals of the new generation, and although fairly high concentrations were met with at Rojri on 29th August and at Derawar on 30 and 31 August and 1 September (the density being about 500 to 600 per square mile), few were noticeable later on in these areas.

Dera Ghazi Khan area. This area was visited by the end of October, when, besides adults, small numbers of hoppers were noted on bushes of *Aerua tomentosa* (*javanica*) near Dera Ghazi Khan and Tibbi Kasrani. Presumably these hoppers represent a late brood induced by the August rains. It may be recalled that similar breeding was observed in this area in October, 1933.

In the Bikaner-Jaisalmer areas, only stray locusts were noticed in October and November. In December, 5 locusts were found at Nachna (Jaisalmer State) on 14 December and 2 at Phalodi (Marwar) on the 18th. Possibly these locusts represent the over-wintering remnants of the monsoon brood, the main body having migrated very early in the season in 1934.

Monthly Meteorological Data for August-November 1934 in West Rajputana

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain-fall
	Mean Max. in Degrees F.	Highest Max. in Degrees F.	Date	8 A.M. Percent	5 P.M. Percent	8 A.M.	5 P.M.		
August 1934									
Bikaner	..	..	..	75	54	SW; E; NE	SW; S	3.6	11.5
Jodhpur	90·5	99	1-viii	85	67	SW;	SW; S	9.6	9·28
Barmer	92.3	100	1, 7-viii	83	64	SW; W; S	SW; S	6.7	6·94
September 1934.									
Bikaner	..	..	..	58	32	SW; W	SW; S; W	1.2	0·55
Jodhpur	93.2	101	29, 30-ix	72	47	SW; W; Cm	SW; W; NW	3.0	0.46
Barmer	94.2	102	30-ix	67	45	W; NW; SW; S	S; SW; W	3.5	Nil
October 1934.									
Bikaner	96.3	97	25, 28-x	26	11	SW; SE; S; W	SW; W; N; NE	0.1	Nil
odhpur	96.5	102	1, 2,-x	40	17	Cm; NE; SW	SW; Cm; NE	0.9	Nil
Ba mer	97.1	102	1, 2-x	47	28	Cm; W; NW	W; NW; Cm.	0.3	Nil
November 1934.									
Bikaner	87.0	93	2-xi	31	15	SE; S; SW	W; NW; Cm.	0.5	Nil
Jodhpur	89.5	94	1, 11-xi	57	17	NE; Cm; N	NE; N; SW	2.0	Nil
Barmer	89.8	96	1, 11-xi	46	29	NW; Cm; N	N; NW; NE	2.4	Nil

The monsoon practically withdrew from west Rajputana early in September, and the general rise of temperature in September and October, the fall of atmospheric humidity and the disappearance of clouds in the skies during the autumn months contributed to the development of conditions of high saturation deficiency in the desert areas—evidently unfavourable to locust habitation. The appearance of northerly and north-easterly winds during October and November had presumably directed the migration towards the south-west.

A collection of 42 specimens from various localities in the Sind-Rajputana areas during September, October and November showed the following biometrical index: 67S : 33T : 0G : : 49(6) : 51(7).

Lasbela area. By the end of August, the hoppers had changed into adults, and were no more seen in the Lasbela area during September. In August, the locust population was computed to be about 32 per square mile, but during September it rose to about 149 per square mile. As the rise cannot be ascribed to local increase, it must evidently have been due to the entry of locusts from outside. It may be recalled in this connection that there was a distinct decrease in numbers in the Sind-Rajputana area during September and the following months. The average density per square mile, for the month of October was 87, for November 50, and for December 19. A gradual decrease in the population is thus evident. While no locusts were met with in the Hinidan area, fairly good numbers were observed on the reks of the Hingol area during September and November, the average density being 264 for September and 110 for November.

Except for one single specimen of the 2nd December 1934 collected at Ambagh, no locusts from the Sonmiani rek areas have been preserved, but fortunately some specimens from the Hingol areas collected during September and November were available for examination. Most of the locusts had either pinkish hind-wings or light yellow or hyaline wings with pinkish bases, indicating that they were mostly migrants. The results of an analysis were as follows: 73S:18T:9G::36(6):64(7).

Mekran area. On account of the continued drought on the Mekran reks, locusts were very scarce during autumn. Even in the Gwadar area, where the population was fairly high in spring and summer, only three individuals were met with in the whole of the Gwadar-Pishukan-Jiwni reks in September, two in October and none in November. At Pasni only two specimens were found in September and none during October and November. It was only after the fall of rain in the middle of December that locusts began to appear at Pasni and Gwadar. None was found during October and November in the Kulanch area as well. In the Ormara area no locusts were noticed during a visit in August-September, and a single locust was met with at Rumra during a tour in December.

In the hinterland of Mekran, on the other hand, two locusts were found at Mand in the Kech valley in September ; and in the Kech-Parom-Buleda areas, between the 26th October and the 12th November, five specimens were found in the Kech valley between Turbat and Mand and 9 locusts at Wakai, Parom and Buleda. No specimens have unfortunately been preserved, but it is not improbable that these individuals were migrants from the Rajputana area.

An examination of nine specimens collected at Pasni and Gwadar during October and December indicated that the forms of this period were generally dark purplish brown with conspicuous mauve-coloured wing-bases. An analysis of the biometrical characters indicated the facies: 78S:22T:0G::22(6):78(7).

Swarm movements in 1934. Certain movements reported to have occurred during the months of January and February 1934 have already been mentioned in connection with the swarm movements of 1933. A report was received by the Central Locust Bureau, Delhi, about the appearance of a swarm in the Puranpur tehsil, Pilibhit district, United Provinces, on the evening of the 20th July 1934, which was said to have entered the tehsil from the east and passed on towards the west without alighting on the ground. The report was, however, not accompanied by specimens, nor was it confirmed by the United Provinces Entomologist.

Summary of the main data for 1934.

The following were the main events in the development of the solitary phase locust in the Indian area during the year 1934: (1) As a result of prolonged breeding in north Rajputana during the autumn of 1933, a large body of solitary locusts was present during November and December 1933 in the northern areas, where they over-wintered. Most of these locusts were marked by the presence of algal growths on their wings, the development of which was apparently favoured by the prevalence of fogs accompanied by conditions of cool temperatures and high humidity, while over-wintering among the bushes in the desert. (2) The prevalence of a drought throughout Mekran—both on the coast and in the interior—was associated with a complete lack of spring breeding, with the exception presumably

STATEMENT IV

Results of Locust Surveys—1934

(The figures present the average population per square mile for the whole month in the areas surveyed and 'H' presents occurrense of breeding)

Seasons	Months	BALUCHISTAN										SIND-RAJPUTANA DESERT						
		MEKRAN							LASBELA									
		Gwadar Pishukan.	Pasni Reks (Int: surveys)	Ormara	Kech	Panjgur	Kulanch Dasht	Kolwa	Hingol	Ambagh Reks (Int: surveys)	Hinidan-Bela	Sind Kachhi	S.W. Punjab Bhawalpur	Chachro (Int: surveys	Thar-Mallani	E. Jaisalmer W. Bikaner	E. Bikaner	Sardar-Shahr. (Int. surveys)
Winter	Dec. 1933 .	186	135		206	Nil	101			983					32	197		
	Jan. 1934 .	55	46				7			316		8	Nil		35			
	Feb. 1934 .	98	159				31			218		Nil	24		Nil	35	Nil	
Spring	March 1934	455	79			67	63		490	360		Nil	2	Nil	Nil	39		
	April 1934	507	114	57	Nil			80		37	10	48	16		Nil	26	7	
	May 1934	520	46		Nil	Nil	139		320	89		Nil	3	12	Nil	66		

Seasons	Months	BALUCHISTAN										SIND-RAJPUTANA DESERT						
		MEKRAN							LASBELA									
		Gwadar Pishukan.	Pasni Reks (Int. surveys)	Ormara	Kech	Panjgur	Kulanch Dasht	Kolwa	Hingol	Ambagh Reks (Int. surveys)	Hinidan Bela	Sind Kachhi	S. W. Punjab Bahawalpur	Chachro (Int. Sur. veys	Thar, Mallani	E. Jaisalmer W. Bikaner	E. Bikaner	Sardar-Shahr. (Int. Surveys).
Summer	June 1934	465	38							40	17	Nil	9	9	2	155		
	July 1934	321	8	Nil				55	98	H 19		Nil	H Nil	H 22	H 4	H Nil		H 27
	August 1934	75	6			144	5			H 32	Nil	Nil	158	H 174	H 7	H 54		H 10
Autumn	Sept. 1934	21	3	Nil					264	149			96	H 91	18	H 11	Nil	14
	Oct. 1934 .	12	Nil		19		Nil			87	Nil		H 34	H 115	21	24		Nil
	Nov. 1934	Nil	Nil			83	Nil	Nil	110	50		Nil	H 24	28	5	10		Nil

of the Jask area of Iranian Mekran, where good rain had been received in March (3) With the receipt of early rainfall by the end of June, the fairly large body of over-wintered locusts present in the desert laid eggs, and a light, though wide-spread, breeding followed. There were, in addition, considerable numbers of spring-bred migrants from the west, which were seen all over the desert and which also bred. (4) Owing to drought in July, further breeding was checked, and the over-wintered generation disappeared by the end of the month. In spite of heavy rainfall in August there was little of late breeding. (5) With an early retreat of the monsoon from the Rajputana region, most of the locusts left the area during September-October. Very few were noticeable in the desert areas during December. (6) There was presumptive evidence of a transference of the locust population by migration into Lasbela in September-October and into Mekran in October-December.

CHAPTER IV

ACCOUNT OF EVENTS IN THE YEAR 1935

Weather notes for 1935.

Winter rainfall 1933-35. Altogether about 48 disturbances passed from the direction of Iraq and Iran over Baluchistan and North-West India between October 1934 and May 1935. The winter of 1934-35 was marked by heavy and even copious rainfall in many parts of Baluchistan and southern Iran. A fair amount of rain fell during the latter part of November 1934 in the Bushire area and in eastern Arabia. During the first half of December, 1934, good falls were recorded at Bushire, Jask, Muscat and Sharjah, as also in Upper Baluchistan. Between 21 and 27 December, heavy rainfall was caused by one of the disturbances at Jask, Muscat, Gwadar, Pasni and Ormara and in the hinterland. There were some heavy falls in the Gwadar-Charbar-Pasni sector between 6 and 10 January during the passage of one of the disturbances, in the rear of which a severe cold wave developed all over northern India and lasted from 12 to 18 January. Between 21 and 24 January, rain fell at Muscat and Charbar and in parts of Upper Baluchistan. Between 26 and 31 January, the last disturbance of the month developed into a well-marked depression off the Sind-Mekran Coast and occasioned widespread rainfall in Mekran, Upper Baluchistan, Sind, Punjab and Rajputana: Ormara 4·50 in., Pasni 2·70 in., Ambagh 0·90 in. and Barmer 1 in. In February, there was a further spell of good and widespread rainfall all over the Persian Gulf, eastern Arabia and the Baluchistan area: *Persian Gulf and Oman region*: Bushire 2·75 in., Henjam 3 in., Jask 5·90 in., Bahrein 1·30 in., Charbar 1·25 in., and Sharjah 3·50 in., *Baluchistan area*: Gwadar 0·84 in., Pasni 3 in., Ormara 4 in., and Panjgur 1·50 in.

After 15 February, there was little rainfall on the coastal areas, as a result of the seasonal retreat of the high pressure zone to more northern latitudes. There were light showers in Upper Baluchistan and Rajputana between 26 and 29 March, and a few good falls between 4 and 7 April in the Ormara-Lasbela-Karachi sector and in Upper Baluchistan and again between 13 and 18 April.

Monthly rainfall data for winter-spring season 1934-35

Localities	Nov. 34	Dec. 34	Jan. 35	Feb. 35	March 35	April 35	May 35
Iran.							
Henjam	..	1·83	0·89	3·70	..	0·47	..
Jask	..	3·46	1·29	5·91	0·04	..	..
Charbar	..	0·79	4·05	1·57	..	0·06	..
East Arabia.							
Bahrein	0·35	0·73	..	1·32	0·45	0·27	..
Muscat	0·02	1·86	3·77	2·10	..	0·23	0·09
Sharjah	0·02	1·78	0·08	4·16	..	..	..
Baluchistan.							
Pasni	..	1·66	6·74	2·93	..	0·11	..
Gwadar	..	5·50	4·69	0·84	..	0·01	..
Ormara	..	1·82	3·44	6·98	..	2·05	..
Turbat	..	1·59	2·72	3·85	0·29	2·14	..
Panjgur	0·20	2·68	1·10	2·48	..	2·06	0·08
Gandhawa	..	0·91	0·62	1·51	..	0·21	..
Sibi	..	1·64	1·00	2·11	0·06	0·28	..
Quetta	..	3·70	1·64	4·10	0·62	2·72	0·49

It is thus seen that winter ra.. fall in the Baluchistan areas was early as well as heavy during the season 1934-35. In the Indian Desert areas, scattered showers fell in January, February and April, especially in the tracts around Bikaner and Barmer.

Monsoon rainfall, 1935. The pre-monsoon period was marked by an absence of rainfall and the prevalence of high day temperatures in North-West India, Naushahro in Sind recording 119°F. on 29 June. The monsoon established itself in the Indian areas only by the middle of June and extended its influence to Central India and East Rajputana only by the last week. The first heavy falls in the desert occurred in the course of the advance of a depression from the Orissa coast into the interior between 7 and 13 July. Five to six inches of rain were recorded during July, in many parts, but the monsoon did not extend into western Sind or into Baluchistan. From 23 July to 15 August, there was little rainfall in western Rajputana. During the second half of August, fairly good falls were received in Bikaner, Bahawalpur and North Sind, under the influence of a depression from the Bay of Bengal, but only light rain in the rest of the desert. During the first fortnight of September, however, comparatively good rainfall was recorded in many parts of the desert, the total fall varying from two to three inches. The monsoon withdrew from North-West India from 20 September, after which dry weather prevailed.

Monthly Rainfall Data for the Monsoon Period—1935

Localities	May	June	July	August	September
Rajputana Area.					
Bikaner	..	0·08	5·28	3·52	2·48
Sardarshahr	..	0·91	4·60	0·34	1·78
Nohar	..	..	4·72	2·60	0·20
Jaisalmer	..	..	5·23	0·21	0·43
Bap	..	..	4·64	3·57	2·64
Jodhpur	0·18	0·07	5·56	0·76	2·89
Barmer	0·03	..	6·21	1·01	2·45
Sind Area.					
Chachro	..	..	8·18	2·47	0·49
Karachi	..	..	0·31	0·19	0·01
Jacobabad	..	..	0·90	1·46	..
South Punjab.					
Hissar	0·15	0·15	8·96	3·32	3·42
Dera Ghazi Khan	..	0·39	0·13	..	..
Khanpur	0·11	0·30	4·18	1·03	0·05
Baluchistan Area.					
Gandhawa	..	..	2·32	0·06	..
Sibi	..	..	0·68	0·56	..
Bela	0·20	0·29	0·48	0·08	0·17
Ambagh	..	..	0·38	0·07	0·05
Ormara	..	..	0·02	..	..
Pasni	..	..	..	..	..
Panjgur	0·08	..	..	..	..
Turbat	..	..	..	..	..

From the table it may be seen that the monsoon was a complete failure in the Karachi, Lasbela and Mekran areas, as also in the Dera Ghazikhan district, while in the desert areas, rainfall was greatly in defect in most places during June and August.

Observations on locust distribution during 1935
(*Vide* Statement V)

1. Winter period 1934-35.

The Sind-Rajputana desert area. Apparently there was no over-wintering in the Thar-Mallani area during December, January and February since no locusts were found anywhere, except for a single locust reported but not captured by a fieldman on 6 January, 1935, between Kantio and Chachro.

In the Jaisalmer-Bikaner areas, a few locusts, about 100 per square mile were noted at Nachna (Jaisalmer) on 14 December and at Phalodi (Marwar) on 18 December. In February, 11 specimens were found at Nokh on the 8th and five more at Girasar on the 10th, (density about 100 per square mile). No locusts were, however, met with elsewhere in the Jaisalmer, Bikaner and Bahawalpur areas. It is presumed that the thin locust population noted in December and February formed part of the second generation produced in these parts as a result of the light breeding induced by the heavy rainfall of August 1934. Of the sixteen preserved specimens found in February, 14 were *solitaria* and two *transiens;* and the biometrical facies was 88S:12T:0G::31(6):69(7).

The Lasbela area. During December 1934, small numbers were met with on the Ambagh reks (density about 19 per square mile). No locusts were found in January, and none also in February, except for a single one at Ambagh on 3 February. In the Hingol area, however, a light population of a density of about 23 per square mile, was found in the middle of February, which were mostly of the *solitaria* and seven eye-striped type.

It was, thus, obvious that unlike the previous year no large bodies of over-wintering locusts were present either in the Lasbela area or in the Sind-Rajputana desert. As it was suspected that the apparent absence of locusts might have been due to their passing the winter hidden at the base of desert bushes or inside rat-holes, a searching examination of all likely hiding places was made during January, February and March in several localities, viz. at Derawar in Bahawalpur, at Chachro and Rahim-ki-bazaar in the Thar area and at Ambagh in Lasbela, but without finding any. At Chachro, thick thorn fences bounding cultivated fields were lifted up and examined, and although a few of the large grasshoppers, such as *Cyrtacanthacris tatarica, Anacridium egyptium* and *Euprepocnemis alacris,* were found hiding underneath, no specimens of the Desert Locust were met with. [It may, on the other hand, be mentioned that during the winter of 1936-37, when over-wintering occurred in the Nokh area, several specimens of live, as well as dead, locusts were noticed at the base of bushes in the desert.] There appears, therefore, to be little doubt that during the winter months of 1934-35 few locusts were really present in the Lasbela, Sind and Rajputana areas.

The Mekran area. Locusts were practically absent in the reks of Gwadar and Pasni in the beginning of December, 1934, but with the fall of good winter rains by the middle of the month, they were found appearing in small numbers all along the coastal areas. As already stated, the locust population noticed on the Mekran reks was characterized by a preponderance of *solitaria* ratios and seven eye-striped forms. They were, moreover, generally dark purplish brown and marked by deep mauve tinge at the base of the wings. As the general facies was very different from what was noted in summer, the winter forms were apparently migrants from outside.

Since, in fact, such forms had begun to appear at Gwadar as early as October, it is obvious that the autumn influx of migrants had commenced fairly early in Mekran, though owing to the extreme drought and the lack

of green vegetation, few locusts had any inducement to settle on the rek areas till the advent of the winter rains.

Atmospheric temperatures were comparatively high throughout December 1934, and even the first week of January 1935 was fairly warm. It was not till the advent of the cold wave in mid-January that winter really set in. While the warm weather lasted, locusts introduced in large field cages erected on the reks at Pasni were found actively pairing and laying eggs, and it is not unlikely that oviposition had likewise taken place in nature at that period.

During the winter months, a sparse locust population ranging in density from 50 to 300 per square mile was noted on the Pasni and Gwadar-Pishukan reks. A collection of 79 locusts of the period—January to March 1935, was found to have the facies: 76S:23T:1G: :34(6):66(7), clearly indicating that the population found then was more or less homogeneous with that of the period October-December 1934, which, as already noted, had the characters: 78S:22T:0G::22(6):78(7).

No locusts were noticed at this time anywhere in the interior of Mekran

II. Spring period, 1935

Sind-Rajputana area. In the Bikaner area, two specimens—both of which were *solitaria* males with seven eye-stripes—were found on 29 March at Sahwa, evidently representatives of light concentrations over-wintering in these areas. No further locusts were met with in the Jaisalmer-Bikaner areas till 29 May, when a *transiens* female with six-striped eyes and yellowish wings was collected at Nokh. In the Thar-Mallani areas also, none was noted during surveys till 17 May when the first individual of the season was found near Chachro. On 22 May, two more locusts were noted and another on the 27th—all of them at Chachro. A female collected on the 22nd was a form with six eye-stripes, *transiens* ratios and mauve-coloured wing-base, presumably a migrant.

Lasbela area. Except for two specimens collected on two days in April and for two more in the course of two surveys in May, locusts were not met with on the Ambagh-Sonmiani reks during spring in spite of fair rainfall. Nor were any seen in the Hinidan area in the interior during visits in April and May. On the other hand, in the Hingol coastal reks, small numbers (density about 12 per square mile) were found during a visit paid in the later half of March. In the course of a tour carried out in the Hingol area between 20 April and 9 May, a larger number of locusts was noticeable in the reks (the average density being about 64 square mile), and a biometrical analysis of 11 specimens showed that five were *solitaria,* three *transiens* and three *gregaria.* Eye-stripes were distinct only in seven, of which only one was of the 7-striped type. The biometrical facies was of the type: 46S:27T:27G::89(6):11(7). Some had deep yellow wings—presumably the old brood, while others either hyaline or light yellow wings, being evidently recently fledged. Some of the latter were evidently locally bred ones, but the rest were possibly derived from the Ormara area, where good breeding had been noted during April. There was, on the whole, distinct evidence as to a change in the character of the population.

The Kachhi area. During visits to Bellpat, Bhag, Shoran, Gandhawa and Nuttall between 25 February and 4 March, the Desert Locust was not located, though a few specimens of *Locusta migratoria* ph. *solitaria* were met with. There was good rainfall in Kachhi in winter, over 1½ in. at Bhag and Gandhawa in February and over three inches in all during the three winter months. This area was not visited again till August, so that it is not possible to say whether breeding had followed in spring, as had happened under similar circumstances in 1937. If breeding had

occurred at all, it should have been very light as there was very little of over-wintering in the desert during the winter of 1934-35.

The Dera Ghazi Khan area. During a visit to this area between 21 and 24 May no adults were located, but three green hoppers (III and IV stages) were found on bushes of *Aerua* in a sandy area to the west of Dera Ghazi Khan. Light breeding had presumably occurred here in April-May as the result of fairly good rainfall, including 1·60 in. in April.

The Mekran area. 1. *The Mekran littoral.* As already stated, locusts were commonly seen on the reks by the beginning of spring. Presumably some oviposition had already taken place during the warm spell in December-January. Hoppers were detected in various places during March, but considering the state of development of the first hoppers collected, it is evident that the earliest hatchings must have occurred during the last week of February. Hoppers were not met with on the Gwadar-Pishukan reks after April, presumably due to an early cessation of winter rains, but in the Pasni and Ormara areas they were seen till the last week of May.

On the Pasni area, however, though not noticeable on the general reks after May, hoppers of different stages, including the first instar, were being found in certain special rek areas till October, and in fact the last hopper of the year was noted as late as 19 November.

A similar prolonged breeding in the special areas had been noted, it may be recalled, during 1933, also a year of heavy rainfall at Pasni, whereas in 1934, a year of drought, no breeding had occurred anywhere. These special areas, where locust breeding was found persisting long after the cessation of rainfall, were thoroughly investigated during 1935. They were, in the main, found to consist of sandy locations in which the soil moisture was present sufficiently near the surface to render oviposition by locusts possible. In certain cases, the moist patches were found either at the base of or between large sand-dunes. The rain-water impounded in the interior of these dunes and prevented from percolating into the ground by impervious clay strata at their base, oozes out from their edges and makes the soil in the neighbourhood damp, and this induces a comparatively luxuriant growth of bush vegetation in such areas. In other cases, suitable spots for oviposition were found on the tops or sides of large dunes, wherever the south-west wind had swept the loose sand off the surface, laying bare the moister layers below. For testing the possibility of such oviposition, three pairs of locusts were confined in a small field cage, the open bottom of which was placed directly on the top of a large sand-dune, towards the end of July 1935, and by the middle of August, two egg-masses were found laid in the soil, which hatched out normally in the laboratory on transfer into a tube of moist sand. In this case, the females had apparently bored through an inch-and-a-half of dry sand before depositing the eggs in the moist layers below.

The first adult of the new generation was noted at Pasni on 8 April, while in Pishukan the new brood was first collected on the 6th. By May, the old generation had mostly disappeared. The majority of the hoppers noted on the reks in spring were of the green type, though a few brownish ones with dark patches were also noted.

An examination of 55 locusts collected from the Mekran rek areas in April-May gave the following analysis: 62S:29T:9G::67(6):33(7), indicating a definite rise in the proportion of *transiens* and *gregaria* forms, as well as of the six-striped type. It was, however, only in the Pishukan-Jiwni-Gwadar areas that all the individuals with *gregaria* ratios were collected, most of them, moreover, in the month of April. A batch of 26 specimens from these areas in April had the facies: 50S:34T:

16G: :87(6):13(7), whereas in the collections from Pasni and Ormara for April, there was a higher proportion of *solitaria* ratios and 7 eye-stripes. On the other hand, a batch of 13 collected in May from the Gwadar-Pishukan areas consisted of 9 *solitaria,* 3 *transiens* and 1 *gregaria;* the facies being: 69S:23T:8G: :42(6):58(7), an analysis more or less in accordance with the characters of the population of the Pasni-Ormara reks in April-May.

Moreover, the collections made in the Gwadar-Pishukan areas in April consisted almost entirely of recently fledged forms with hyaline or light yellow wings, and it is obvious that hoppers had begun to transform very early in these areas, possibly even by the end of February, since the earliest specimens of the new brood found on 6 April at Pishukan had already acquired a light yellow tinge on the wing. These facts may be correlated with the heavier rainfall in these areas in December, 1934, and the relatively high temperatures that prevailed in south Mekran during December and the first week of January—which probably led to very early breeding on these reks, and possibly also in the adjoining parts of Iranian Mekran. As rainfall had occurred in these areas in December after a prolonged drought of nearly 18 months' duration, vegetation on these areas was presumably more or less dried up. Fresh shoots were apparently just aprouting when the early batches of hoppers hatched out, which presumably had to wander about a good deal for finding food. The appearance of the *gregaria* components in the population might be attributed to the high activity of the early batches.

Such early breeding should be considered to have been even more likely in a more southerly clime like that of Oman in eastern Arabia, and a migration from this area should not have been unlikely.

2. *The Mekran interior.* During a tour in Kolwa, Panjgur, Buleda and Kech areas between 20 February and 15 March, no locusts were met with anywhere, except for a single male (with 6 eye-stripes and E/F ratio 1·99 and yellowish wings) obtained from the Mand Area, on 12 March, 1935. During the next tour in the Kolwa, Panjgur and Buleda areas (5 to 20 April), locusts were noticed in fair numbers in the Kech-Kolwa valley, (Sami, Hoshap, Rodkan, Chambar-Kalat and Awaran), and also in the Panjgur and Buleda valleys. On 8 April, two fifth instar hoppers were collected between Rodhkan and Chambar-Kalat in Kolwa, indicating that oviposition had occurred here by end of February and led to light breeding in March. Among 17 specimens collected in the Kolwa-Panjgur-Buleda areas, wings were hyaline in one, brownish yellow in two and light to bright yellow in the rest. All had six-striped eyes. Out of 12 locusts found in the Kolwa valley, six were *solitaria,* two *transiens* and four *gregaria.* The population was evidently very different from the type known to have been present in January-March on the coastal areas, with a preponderance of 7 eye-striped forms and an absence of *gregaria* ratios. On the other hand, there was a similarity between the Kolwa population of April and that found in the Gwadar reks in April. Apparently, both of them belonged to a new brood developed in the Gwadar-Pishukan areas or, perhaps further west in Iranian Mekran or in Oman area.

The Kulanch area was surveyed between 6 and 12 April, when fair numbers of locusts of the old as well as of the new generation were met with. A few hoppers were also found at Kandasole and Chukin Rek. The first adults of the new generation were collected on the 6th April at Kandasole. Quite large numbers were found in Kulanch, especially at Kandasole and on Sawar Kaur reks, during surveys between 8 and 14 May. A few IV and V stage hoppers were also observed. A small collection of 13 locusts caught in May in the Kulanch area was composed of six samples of *solitaria,* six of *transiens,* and one of *gregaria,* and all were

six-striped. The population showed a fairly distinct affinity with that noted in the Gwadar-Pishukan area in April.

The Kech, Parom and Buleda areas were next visited between 12 and 23 May, when fair numbers of locusts were found, especially between Nasirabad and Mand, around Sar-i-Parom and Buleda, as also a few hoppers between Tump and Mand. Such a find of hoppers and adults in the Nasirabad area in May is of particular significance in connection with the development of a fairly typical *'outbreak centre'* on the Shashtal rek in the vicinity of Nasirabad in May-June, which will be dealt with subsequently. An examination of 13 specimens collected gave the following results: *solitaria* 4, *transiens* 9, and *gregaria* nil; and 6-striped forms 11 and 7-striped 2. A few had brownish yellow wings indicative of the old generation, while the rest had either hyaline or light to bright yellow wings—being obviously a recent brood. Although this might have been partly produced locally, the main part was probably made up of migrants from the coastal areas.

Although as a result of local breeding a distinct rise in population density was perceptible in the Mekran coastal reks during April and May, a definite drop in the population was noticeable by the last week of May, presumably due to the occurrence of emigration.

III. Summer period, 1935

A. Locust activity in June, 1935

(a) *Sind-Rajputana areas.* The first locusts of the season were found at Chachro during the latter half of May. Further specimens were met with only in the second fortnight of June, 4 locusts around Chachro and three at other localities. At Barmer, the earliest specimen was noticed on 8 June, and a dozen more by the end of the month. At Nokh, the first locust was collected on 29 May, and during June, quite a large number, as many as, 62. On the other hand, at Sardarshahr the first locust of the season was found only on 25 June, and a second one on the 28th.

The collections of June were examined biometrically. Ten specimens collected in the Thar-Mallani area indicated the facies: 30S:50T:20G::89(6):11(7). A collection of 58 locusts from Nokh yielded the following analysis: 51S:37T:12G::90(6):10(7). A total collection of 72 specimens from the whole of the Sind-Rajputana area during May and June indicated the following biometrical facies: 48S:39T:13G::89(6):11(7).

These characters would indicate a certain amount of affinity with the April population of the Gwadar-Pishukan rek areas. Most of the specimens had yellowish wings, and a fair percentage also had a tinge of mauve at their base.

(b) *Lasbela area.* During June, fairly good numbers were found in the Ambagh rek areas, especially in the latter half of the month. The average density was about 105 per sq. mile for the month. In the Hingol area, a fairly good number was observed especially in the Pohr reks, the average density for the whole area being about 112 per sq. mile. In most specimens, the stripes were conspicuous, the dorsolateral ones being bright bluish brown. The wings were generally light to bright yellow, though hyaline grey in a few cases. Many had a light pink tinge at the base being apparently migrants.

A collection of 23 locusts was composed of: *solitaria* 19, *transiens* 4, and *gregaria* 0; and 6-striped 20, 7-striped 2 (stripes not being clear in one specimen). The biometrical facies was found to be: 83S:17T:0G::91(6):9(7). These characteristics indicate an organic connection with the population found on the Mekran reks in the later stages of development in April-May. The paucity of the higher ratios is somewhat striking.

(c) *Mekran area.* During June, a gradual diminution of population was perceptible both at Gwadar and Pasni, the density being about 175 and 218 per sq. mile respectively. Most of the locusts had developed a rather striking coloration, marked by bright bluish-brown dorsolateral stripes. This type of coloration appears usually to prevail among locusts in the Mekran area at the beginning of summer, possibly due to the action of the bright actinic rays of an unclouded summer sun.

In the Kulanch-Dasht area (2 to 20 June), fair numbers of locusts were met with in many places. Hoppers were also found in fair numbers on plants of 'Kapocham'—(*Chrozophora*) on the bed of the Muksar Kaur near Kuhak and of Kassu Kaur near Bishuli in the Dasht valley (7-8 vi), and also on 'Kapocham' bushes in a *jowar* field on the banks of the Belar Kaur between Ban and Nokbur in Kulanch (17-vi). They were green in colour and included all the different stages. The eggs had presumably been laid in May, and the hoppers probably represented the second spring generation.

B. Development of outbreak centres in Mekran

During the summer of 1935, reports of the occurrence of *gregarious* hoppers were received from the Kalat State authorities, which were of extraordinary interest from the point of view of locust epidemiology. Unfortunately, however, they were received far too late for a proper investigation of the outbreak or for a trial of control measures.

1. *Shashtal area in Kech valley.* The Shashtal area is situated between the beds of the Kech and the Nihing Kaur at the point of their junction to form the Dasht river (see Pl. 15). It is mostly undulating ground, partly made up of low mounds of blown silt or fine sand and partly of deposits of loess and covered with various kinds of bush vegetation. It was reported that parts of this area were cultivated in years of good winter rainfall.

On 14 June, the Naib of Turbat informed the Turbat fieldman that a report of damage to crops by hopper bands had been received from Shashtal and the infested area was visited by the latter on the 17th. He was informed by the owner of the field that the infestation had been noticed 'since the last 40 days', when bands of black hoppers, hatched on the adjoining sandy *reks*, had been damaging his field of *jowar* and pulses. The hoppers, had later on turned yellow in colour, and had ultimately disappeared 'about ten days ago', after acquiring wings. Certain insectivorous birds, as well as jackals, were observed attacking the hoppers, and the owner himself, with his boys, had been having a repast of some of the fatter hoppers after roasting them. By 17 June, comparatively few locusts could be seen, when the fieldman counted 400 adult locusts (including a few of pink colour) within 800 sq. yards of the field. A few yellow hoppers were also found, as well as several green ones on wild bushes outside the infested area, and also some grey-brown adults. On 6 July, only 33 adult locusts were found in this field; apparently the majority had migrated elsewhere by that time.

From the data gathered by the fieldman, it is obvious that eggs had been laid by the middle of April. Few locusts were found by the survey staff in the Kech Valley in January, February and March, but in April-May, good numbers were met with in the Kech-Kolwa valleys; and the fact that a few hoppers were also noticed would indicate that breeding was then in progress. Since black hoppers are said to have been found in masses in the Shashtal area early in May, it is obvious that oviposition had occurred by the middle of April. Locusts were known to have been present in the Kech-Kolwa area and also in Panjgur and Buleda early in April, and it is possible that as a result of good rainfall early in April

(Turbat had 2·14 in. in April including sharp falls of 1·05 in. on the 3rd and of 0·84 in. on the 4th, and Panjgur 2·06 in. in April including 1·40 in. on the 14th), concentrations of locust adults had formed in favourable situations. It is presumed that Shashtal, by reason of its patches of *jowar* cultivation and its sandy soils, had served, especially after rainfall, as an attraction to passing locusts and thus led to their becoming crowded in this area for purposes of feeding and egg-laying. It is presumed that eggs had been laid partly in the fields themselves and partly in the surrounding *reks*, and after hatching, the hoppers had obviously become further crowded in the *jowar* crop, and developed typical *gregaria* characters. The adult locusts transformed from the hoppers were reported to have mostly disappeared by the time the fieldman reached the area (17th June), but a collection of 58 locusts made by him was, on analysis, found to have the facies: 71S:24T:5G::84(6):6(7). It is possible that the bulk of the *gregaria* forms had migrated from the area, the specimens found by the fieldman being mainly forms developed from the later batches of hoppers or from those that had become comparatively isolated. This supposition is somewhat borne out by the fact that, out of a batch of nine specimens collected in this area three weeks later (on 7 July), 8 were *solitaria*, 1 *transiens* and none *gregaria;* and 3 were 6-*striped* and 6, 7-*striped*, indicating a further diminution of the *gregaria* and *transiens* forms.

2. *Seh-Gazan and Gar areas near Panjgur.* On 22 July, a report was received from the Naib Wazir-i-Azam, Mekran, from camp Pasni, to the effect that the Janishin of Panjgur had noticed infestations by locusts in *jowar* cultivation at Seh-Gazan on the banks of the Rakhshan on 7 July, and at Gar on the Gwargo on the 8th, in the course of revenue work. Both winged locusts and hoppers were present and the hoppers were damaging the leaves and the ear heads. The Turbat fieldman visited these areas on 12 August and made enquiries. He was told that about two months back the cultivators had found masses of small black hoppers emerging from the banks of the river and swamping their crops like a 'flood' and devouring them. The hoppers were reported to have turned into adults early in July, and to have gradually disappeared by the middle of the month, when the 'Gorich' or the dry wind from the north began to blow over the area.

At the time of his visit on 13 August, the fieldman found about 30 individuals, on the whole, at different places in the Seh-Gazan-Gar area, and an analysis of 27 specimens preserved showed the facies to be 48S:41T:11G::36(6):64(7). As in the case of Shashtal, it is probable that the forms with the higher ratios had in great part migrated, leaving only the stragglers behind.

3. *Washuk area in Kharan.* Information on the occurrence of *gregarious* hoppers at the beginning of July at Balgattar and Macho in a part of the sandy desert near Washuk was obtained from a report made by the Nawab of Kharan to the Political Agent, Kalat. In respect of the further history of the hoppers, the Nawab reported that they had been killed by the intense heat of the sands, but it is perhaps more likely that the bands had become dispersed among the scattered vegetation and disappeared after acquiring wings.

Origin of the Panjgur and Kharan infestation. From the data available in regard to the infestations, it may be assumed that eggs had been laid about the middle of May and had hatched by the beginning of June. Surveys carried out in April-May in the interior of Mekran indicated that fair numbers of scattered locusts were present, all over the area. Since no locusts had been found in these areas in January, February and March, it is obvious that those found in April must have been migrants from

outside, and as they had mostly hyaline or light yellow wings, they were evidently a recently developed brood. 46 locusts collected from the interior in April-May were found to have the facies: 43S:46T: 11G: :96(6):4(7). As these tally to a certain extent with those of the coastal population found in April 58S:31T:11G: :75(6):25(7), it is fairly clear that a migration from the coast had been in progress since March. A similar migration from the coast into the hinterland of Mekran is known to have often occurred at this period during the locust cycle of 1926-31 in the case of swarms.

The Washuk area could not be visited on account of the difficulties of access, but Seh-Gazan and Gar were examined by the staff. In the latter two cases, as at Shashtal, the infestation had occurred in *jowar* fields. Presumably the crop itself had served as the attractant to the locusts, and it is conjectured that eggs had been laid partly in the fields themselves, and partly in the immediate vicinity—possibly on the beds or banks of the streams.

The importance of these three cases of breeding has been emphasized by the writer in two of his papers (Rao, 1936, 1937), as they were typical examples of incipient swarming and as the areas had functioned as outbreak centres (*foyers grégarigénes*). As outbreak centre has been defined as a station the ecological conditions of which sometimes provoke the transformation of a species into its swarming phase (phase *gregaria*). (*Proc. III Int. Loc. Confce., London*). Under the conditions prevailing in Mekran in April-May, 1935, these areas were able, by reason of the existence of optimum conditions of atmospheric temperature and soil moisture, and of the presence in abundance of favoured food-plants such as *jowar* and certain weeds, to bring about a concentrated egg-laying and breeding, and thus to provoke the transformation of phase *solitaria* into *gregaria*. These cases are of particular significance in view of the occurrence of a wide-spread incursion of locusts, noticed in many parts of North-West India during July, 1935.

C. *The Locust incursion of July 1935*

During June, 1935, the only developments in regard to locusts was the detection of solitary individuals in small numbers at the various outposts in Lasbela, Sind and Rajputana. In the Mekran coastal areas, a light population was noticeable, apparently made up partly of locally bred individuals and partly of migrants from outside, which was obviously gradually decreasing. In July, however, rather extraordinary events were recorded all over these areas. On the 1st of July, a swarm was reported to have appeared at Shahgarh in Jaisalmer State, on the 4th another at Reti along the Jaisalmer-Bahawalpur borders, and on the 19th and 29th respectively, two more in parts of the Khairpur State. The revenue authorities of Chachro, Badin, Mithi, Johi and Thano Bulakhan sent in reports of the presence in July of large numbers of stray locusts in their areas, and the locust survey staff themselves detected a sudden increase of the locust population at several stations about 12 July. A sudden increase of population of this sort looked rather mysterious at the beginning, but as information gradually began to filter in from various sources, it became apparent that North-West India was experiencing a locust incursion of considerable magnitude during July 1935.

1. *The Mekran reks. Pasni.* As the writer happened to make a fairly long halt at Pasni at the time of the locust incursion, he had the opportunity of making personal observations at the time of its occurrence. During the last week of June and the first week of July, the population density during surveys ranged between 150 to 500 per sq. mile, and the locusts met with were marked by conspicuous bluish-brown stripes. On

the morning of 12 July, at sunrise, several pinkish locusts marked by lively activity were noticeable in the immediate vicinity of the Locust Camp, and during a short survey made in the neighbouring reks, about 131 locusts were observed, indicating a density of about 3,000 per sq. mile. A good many were found to be pinkish in colour, and as they were evidently present in much greater numbers than usual, it was clear that an immigration had occurred. During the following days, specimens of a bright yellow colour (generally associated with mature swarms), were found along with the pink and grey forms among the reks, during surveys. A cursory examination of specimens found after 12 July showed the presence of an unusually large proportion of *gregaria* and *transiens* forms. During surveys in the second fortnight of July, it became apparent that the population was gradually increasing, when an average density of nearly 10,000 per sq. mile was noted, while during the first fortnight of August a density of nearly 14,000 was worked out. By the end of August, however, a definite decrease was noticeable, an average of about 5,200 being noted for the second half of August, and there was a further diminution in numbers during September and October (monthly average being 4,300 and 900 respectively).

It was also noticed that a local shifting of population within the Pasni rek area sometimes occurred. For example, in the middle of July, larger numbers of locusts were found in the northern reks of Pasni such as Gurrani, Deghan and Sadi Reks than in the southern reks (along the coast), such as Adasti and Chur. On the other hand, by the beginning of August, most of the locusts were found congregated in the southern reks. Though there was some evidence of the activity of birds in attacking individual locusts, it was obvious that the decrease in numbers could not be attributed solely to this factor.

In the past, in the course of survey work, it had been noted by many of the staff that, at times, locusts under pursuit showed a tendency to rise high into the air and fly out of sight. Similar cases of high flights were observed at Pasni during July and August during surveys, generally at mid-noon. In addition, instances of high flights, which occurred absolutely spontaneously after sunset, came under the joint observation of the writer and Mr. Taqi Ahsan on three successive evenings,—17, 18, and 19 July, and again on the 25th. While returning to the locust camp after sunset, they found a few individuals rising without any provocation from the ground and ascending with zig-zag flights higher and higher into the air until they disappeared in the dim light of the gloaming. The direction of flight was north-eastwards with the wind. At the time when these observations (18 in all) were made, the screen temperature was between 81° and 83°F. (27°-28°C.) and the air humidity about 80 per cent., but the soil moisture was very low. (The conditions under which the flights occurred are further discussed in the chapter on Ecological Studies). No flights were noticed prior to sunset. After darkness fully set in, it was not possible to continue observations, so that no definite statement can be made as to whether such high flying was continued during night-time. There is, however, reason to believe that night-flying does occur, and is probably even normal, during warm summer nights. Kennedy (1939) also made observations of spontaneous taking-off at dusk on the Red Sea Coast on 25 April 1937 (Air temperature 29°C.) on the part of certain caged locusts, when the cagedoor was purposely kept open. Predtechensky (1935-2, Chap. XXII) states with reference to flights of pink locust swarms in the Persian area in the second week of June, 1930: 'Under the climatic conditions of Baluchistan, locust migrations occurred at this time always in the evening hours and occupied the first part of the night'. These observations might apply with equal effect to non-gregarious individuals, so far as their reactions to the meteorological conditions in summer

are concerned. During the period of the incursion, the arrival of any large influx of migrants could often be readily noticed at sunrise, as also any perceptible diminution of population, both of which are suggestive of nocturnal migratory movements. As cases of spontaneous high flights were rarely noticed during day-time, it is surmised that locust movements probably occur normally only at night.

Gwadar. Whereas only small numbers were met with by the local fieldman during the first week of July in the Gwadar-Pishukan reks, a rather sudden increase of population was noticed from the 12th onwards. At the beginning of July, the density was only about 200 to 300 per sq. mile, but by the end of the month, it had risen to 4,000 to 6,000 per sq. mile. In August there was a further rise to about 10,000 to 12,000, after which there was a gradual decline in density during September and October, to about 500 per sq. mile in the last week of October. After 12 July, the entry of pink and yellow forms was noticed at Gwadar, as at Pasni.

Ormara. A fieldman touring in the Ormara area from 2 to 19 July, found fair numbers on his way from Pasni to Ormara (about 500 per sq. mile) up to the 10th. On the 11th, he observed only ten locusts on the reks around Ormara, but on the 12th, he noticed quite large numbers at the base of the Ormara Hill and was able to collect 594 specimens in a few hours. On the way back to Pasni, however, he did not meet with any unusual numbers. During August, quite large numbers were found at many places, the average density being about 2,880 per sq. mile. By October, the numbers had considerably decreased. The biometrical facies of 60 locusts collected in this area during August was: 15S:65T:20G:: 91(6):9(7), indicating a high percentage of *transiens* and *gregaria* and six-striped forms.

Ambagh. During the first week only a light population was noticeable. The occurrence at Ambagh, at about 7 P.M. on the 10th, of a dust-storm from the north-west accompanied by high winds was reported. The latter was followed by a shower of about 0·30 in., which proved to be the only fall of the monsoon season. On the 12th, he found during a survey of about two miles of the rek area about 200 locusts, many being of pinkish colour. Locusts were numerous during the whole of July, the average for the second fortnight being about 5,700 per sq. mile. There was a considerable diminution during August the average for the month being only about 2,100. There was a further decrease during September.

A biometrical examination of the few specimens preserved showed a high proportion of *transiens* and *gregaria* and of forms with six eye-stripes.

2. *Sind-Rajputana desert—Thar-Mallani area.* At Chachro and Barmer and in the Thar-Mallani area, in general, only small numbers of locusts were being met with till 11 July, the density varying from 100 to 300 per sq. mile. At Barmer, a sudden rise in population was noted on 11 July, 57 locusts being found during survey instead of four observed on the 10th. Large numbers were, thereafter, noticed during the rest of the month. During a tour in the Mallani-Thar area, a sudden increase of locusts was also first met with on the 11th between Dhorimana and Rabasar, and thenceforward a similar high population was observed till the end of the tour on the 22nd at Gadra. During surveys, a perceptible rise of population was noticed on 8 July at Chachro, though it was only from the 12th that very large numbers with a density above 10,000 per sq. mile were observed. This may be correlated with the report by the Patel of Charnor of the flight of a small group of about 200 locusts over Charnor on 7 July at 4 P.M. in the afternoon.

In these areas, the appearance of locusts was associated with the prevalence of heavy winds and rain-storms from the 7th to the 16th under the influence of a Bay depression. Though winds are usually very variable during the progress of a depression, the general experience in Western Rajputana is that the main direction of rain-storms is from north-east to south-west. In the Thar-Mallani area, the popular belief is that locust swarms, in years when they are prevalent, generally arrive from an eastern or north-eastern direction. It is, therefore, presumed that the increase of population noted in these areas about 11 July had been brought about by migration from the northern parts of the desert, where they were obviously present in good numbers, as evidenced by the report of the Hākim of Shahgarh (western Jaisalmer) about a swarm that had passed over the place on 1 July.

Bahawalpur-Jaisalmer-Khairpur areas. No surveys were undertaken in these areas till August. It was reported, however, that a small swarm had been seen on 4 July at Reti (Sind) flying from south-east to north-west. On 19 July, a loose swarm of yellowish locusts is said to have appeared from the north-east in the Faizganj taluka of Khairpur and again another of pink and yellow ones at Makan Dhundh in the same taluka on 29 July, coming from the south and flying eastwards. Since a swarm had passed over Shahgarh on 1 July, and since it was unofficially reported at Nokh that small swarms had been visiting Khairuwala, Nowa and Mohangarh in north Jaisalmer during July, it is probable that locusts had reached these areas much earlier than elsewhere. It is rather unfortunate that survey staff had been withdrawn from these areas early in 1935. Otherwise, valuable clues might have been obtained as to the actual course taken by the incursion.

West Sind and Kachhi. The appearance of scattered locusts was noticed in Karachi area at Manghopir, Habnadi and Gadap during the third week of July. Fairly good concentrations were found at various places, such as Thano Bulakhan, Dadu, Johi and Hairokhan in West Sind towards the close of July, but none in areas of wet cultivation, such as Kambar and Larkana. In the Kachhi area, locusts in fairly good numbers were found in the second week of August at Bhag, Bellpat, Gandhawa and Nuttall either in young *jowar* crops or among clumps of vegetation. Some of the *jowar* fields had been very much damaged, indicating that locusts had visited these crops in numbers sometime back.

East Jaisalmer and Bikaner. Although fair numbers of locusts were observed at Nokh during June, very few were seen during the first fortnight of July, and it was only on 20 July that a rise in population was recorded. Fairly high numbers were noticed during the last week of the month (500 to 2,000 per sq. mile). Good numbers were noted at Chinnu, Nachna and Baru in east Jaisalmer between 17 and 20 July. At Sardarshahr very few were observed during the month, but the find of about 21 locusts at Sonpalsar on 26 July possibly marks the eastern limit of the incursion in 1935.

Upper Baluchistan. No information is available as to whether the incursion reached the uplands, but from consular reports from Zahidan (Iran), it was learnt that some flying locusts had been seen at Nushki by some of the residents in mid-July. This was, however, not confirmed officially.

It is thus seen that a rather sudden increase in the numbers of locusts had been noticed in July over a wide area in North-West India, covering most of the coastal areas of Mekran and Lasbela, many parts of Sind, the Kachhi area, the Khairpur and Bahawalpur desert areas, and the greater part of the Rajputana desert, Sardarshahr forming probably the eastern limit of the incursion.

3. *Biometrical characteristics.*—Collections made in *July* of the population met with in the various parts of this vast area were carefully examined with the following results:—

Area	Total number of specimens examined	Phase Proportions (in percentages)			Eyestripe Proportions (in percentages)	
		Solitaria	*Transiens*	*Gregaria*	Six Stripes	Seven Strips
1. *The Mekran Resk*						
Gwadar Reks. .	34	26	38	36	91	9
Pasni Reks .	57	40	32	28	82	18
Ambagh Reks	13	31	23	46	80	20
Kulanch-Dasht Area	62	2	38	60	92	8
2. *Sind-Rajputana Region*						
Thar-Mallani Area .	187	30	43	27	94	6
East Jaisalmer Area	53	11	49	40	100	0
Bikaner Area .	39	42	32	26	72	28

From the above figures, it is apparent that the population found in the various places after the July incursion was, on the whole, homogeneous being characterised by a high proportion of *gregaria* and *transiens* ratios and of forms with six eye-stripes. During August, there was apparently a further influx of population in various areas, and as may be seen from the results tabulated below, the same biometrical characteristics were maintained, and perhaps even accentuated to a certain extent.

Results of biometrical analysis for August, 1935

Area	Total number of specimens examined	Phase Proportions (in percentages)			Stripe proportions (Percent)	
		Solitaria	*Transiens*	*Gregaria*	Six Stripes	Seven tripes
1. *Mekran Reks*						
Ormara Area .	60	15	65	20	91	9
Pasni-Gwadar Area .	30	0	53	47	93	7
2. *Sind-Rajputana Region*						
Thar-Mallani Area .	60	28	43	30	95	5
E. Jaisalmer-Bahawalpur Areas .	103	13	30	57	94	6
Bikaner Area .	146	19	50	31	90	10

4. *Origin of the incursion.* In a previous publication [Rao, 1936], the writer had dealt with the subject in the light of the data then available to him. Experience obtained in the course of subsequent work has, on the whole, served to confirm the conclusions arrived at in that paper.

Except in the Khairpur-Jaisalmer area, where a few swarms were reported, the incursion experienced in Baluchistan, Sind and Rajputana appears to have occurred in the form of an immigration of large numbers of individuals. Even in the case of the swarms mentioned above, it is probable that they were not flights of gregarious locusts in the true sense, but merely of loose groups of individuals that happened to be flying simultaneously in reaction to the prevailing meteorological conditions.

Whereas flights of large swarms generally attract the notice of local residents and are, therefore, readily reported, observations on the movements of individuals cannot be made except by a specially trained organization. Detection of such movements is specially difficult in sparsely inhabited tracts like Baluchistan and the regions further west in Iran and Arabia, wherefrom the incursion had probably originated.

In these circumstances, direct evidence in regard to the origin of the incursion was not obtainable. On the other hand there is much indirect evidence as to the probable sources from which the incursion might have been derived and the conditions which had, in all probability, contributed to bring about its appearance in India.

In view of the fact that the major part of the incursion population is made up of *gregaria* and *transiens* individuals, it is apparent that they must have been produced as a result of crowded breeding, in an area of spring rainfall. Since it is known that no swarms had been active in any part of North-West India prior to July, 1935, the origin of these forms is doubtless to be connected with the development of incipient swarms in 'outbreak centres' of the type noticed in June-July in the interior of Mekran. It may be recalled that in these areas, the bulk of the adults produced therein were reported to have disappeared shortly after getting wings, and that in the Seh-Gazan and Gar areas, their departure was said to have been due to the development of the dry 'Gorich' wind from the north.

In view, however, of the enormous total number of the individuals concerned in this widespread incursion, it is evident that the few outbreak centres brought to the notice of the Locust Survey staff could not have accounted for the whole population. It is not unlikely that similar other 'outbreak centres' had actually come into existence at that time in the Mekran area, but had not been reported. Furthermore, it should not be considered improbable that small incipient swarms had also developed unnoticed among the natural vegetation of the country in favourable localities. Though, taken individually, such cases should not have been of much consequence, yet their cumulative effect in swelling the total numbers should have been quite considerable. As an instance in point, the find of fair numbers of hoppers on bushes of *Chrozophora* on many riverbeds in the Kulanch area in June may be cited.

Again, the area included in British Baluchistan—to the confines of which our present investigations have been restricted, is merely part of a larger region of locust habitat stretching into Iran and eastern Arabia. It is known from available meteorological data that good rainfall had been received at Jask, Muscat and Sharjah in December 1934, at Charbar and Muscat in January, 1935 and at all places in Iranian Mekran and eastern Arabia in February, 1935, so that conditions there were evidently as favourable for locust breeding as in British Mekran. It is, therefore, not improbable that outbreak centres had similarly developed in the interior of the country and led to the formation of similar incipient swarms.

During times of mass-multiplication, swarms produced in Iranian Mekran are known generally to travel eastwards in May-June and enter British Mekran. Presumably the migrations of locust individuals produced in the Iranian area had taken the same direction, and had led to

their amalgamation with the locusts bred in Mekran. In this connection, a study of the meteorological conditions prevalent in Mekran in early summer is of much importance, as locust movements at this part of the year are evidently activated by them.

5. *Factors controlling the course and the direction of the incursion.*— The following meteorological data have been extracted from the Monthly Weather Data for 1935, of the India Meteorological Department in connection with the study of the factors leading to locust migration in summer from the winter rain areas of Iranian and British Baluchistan.

Monthly Meteorological Data for April-July, 1935 for the Western Areas

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain
	Mean Max. in Degrees F.	Highest Max. in Degrees F.	Date	8 A.M.	5 P.M.	8 A.M.	5 P.M.		
April 1935.—				Per-cent	Per-cent				(Inches)
Seistan (Iran)	84.8	98	26-iv	56	39	S; SE; Cm	N; NE	1.6	Nil
Nokkundi	87.6	97	24, 25-iv	85	27	E; N; NW	NW; N; SW	2.1	0·10
Dalbandin	83.9	94	23, 25-iv	56	27	Cm; N; NE	SW; S; NW	3.5	6·90
Panjgur .	85.2	95	25, 30-iv	52	30	NE; N; E	SW; S; N	1.9	2.00
Pasni .	87.3	93	21-iv	78	73	W; NW	SW; W; S	2.5	0·11
Jask (Iran)	85.4	93	28-iv	68	64	N; E; Cm	W; SW; S	1.2	Nil
Sharjah (Oman)	85·4	92	1-iv	69	58	S; SE ; SW	NW; W; SW	1·9	Nil
Sibi .	91.5	105	26-iv	35	..	Cm; N; NE	..	3.3	0.28
May, 1935.—									
Seistan (Iran)	91.7	102	30-v	44	34	N; NW	N; NW; Cm	1·2	Nil
Nokkundi	98·1	105	14,31-v	41	30	N; NW; E	NW; N; W	1·4	Nil
Dalbandin	96.4	103	28-v	41	20	Cm; SW; NE	SW; S; W	1·0	0·08
Panjgur	97.2	106	31-v	42	31	Cm; NE; N	N; NW; SW	0.6	0.08
Pasni .	93.1	101	4, 22, 23-v	77	73	W; Cm; NW	SW; W	1.8	Nil
Jask (Iran)	91.4	97	26, 27-v	65	63	E; W; NW	SW; W	2.0	Nil
Sharjah (Oman)	90.4	97	2, 3-v	62	58	S; Cm; SE	SW; NW	1.5	Nil
Sibi .	107.2	114	28-v	20	..	NW; Cm; N	..	0·8	Nil
June 1935.—									
Seistan (Iran)	96.8	106	27-vi	43	32	N; NW	N; NW	0.7	Nil
Nokkundi	103.7	113	20, 29-v	31	25	N; NW	N; NW	1.7	Nil
Dalbandin	103.1	112	29-vi	39	30	Cm. SW; W	NW; SW; W	2.0	Nil
Panjgur .	102.3	110	27-vi	46	31	Cm; N; W	NW; N	0.7	Nil
Pasni .	95.7	108	4-vi	70	68	W; SW; NW	SW; W	3.2	Nil
Jask (Iran)	97.7	104	4, 29-vi	65	62	E; Cm; NW	SW; W; SE	0.3	Nil
Sharjah (Oman)	99.3	112	17-vi	60	60	Cm; S	W; N; NW	Nil	Nil
Sibi .	113.4	123	30-vi	23	..	Cm. S; W	..	0.8	Nil
July 1935.—									
Seistan (Iran)	103.6	112	30-vii	29	25	NW; N	NW; N	0.1	Nil
Nokkundi	107.3	115	16-vii	43	31	NW; N	N; NW	1.1	Nil
Dalbandin	106.8	113	16-vii	37	29	Cm; SW; W	SW; SE; S	0.5	Nil
Panjgur .	104.9	108	4 days	54	28	W; Cm; SW; N	NW; N; SW	1.1	Nil
Pasni .	90.2	97	9-vii	81	76	Cm; SW; W	SW; W;S	8.8	Nil
Jask (Iran)	96.7	106	1-vii	75	66	E; W; NE	S; SE; W	3.5	Nil
Sharjah (Oman)	101.4	110	24-vii	47	55	Cm; S	W; NW; N	7.1	Nil
Sibi .	108.1	114	7-vii	52	..	Cm; S	..	1.6	0.68

From the above data, it may be noticed that a change towards drier and hotter conditions set in during May in the interior of the country as, for example, at Seistan, Nokkundi, Dalbandin and Panjgur. These conditions are seen to have been considerably accentuated in June and July, especially in the afternoons. In the coastal areas as at Pasni and Jask, on the other hand, the setting in of the moist south-west wind from the sea appears to have had the effect of raising the humidity and moderating the heat of the summer months. In the Mekran area the south-west wind, which blows from the coast into the interior of Baluchistan, reaches inland areas like Turbat and Panjgur, though, however, as it penetrates into the interior of the country, it gradually loses its moisture content and becomes a comparatively dry and hot current. At intervals, the south-west wind loses its strength and fails to reach the interior, where it is then replaced by a much drier and hotter wind from the Iranian areas, which has the effect of raising the general temperature to a high degree. The general result is the production of conditions of extreme desiccation and high saturation deficiency, which cause the locusts to leave the area.

During the greater part of June, when the south-west current was blowing strongly, it is presumed that most of the locusts produced in the Mekran area, or present there at that period, were transported by the wind towards Sind and Kachhi and formed the stock from which the small swarms reported in the Jaisalmer, Bahawalpur and Khairpur areas were derived. It is surmised that these locusts were, at the beginning of July, present scattered in fair numbers in many parts of the northern areas of the Indian Desert and that some of these were later on carried southwards into the Thar-Mallani areas by the storms associated with the advance of the Bay depression in the second week of July.

The incursion of forms that occurred in the Mekran coastal reks about 12 July—between Gwadar and Ambagh, would appear, on the other hand, to be due to the development of strong northerly or north-westerly winds —known in Baluchistan as the 'Gorich'—in the Turbat-Panjgur area in the first fortnight of July. As may be seen from the statement of the recorded wind directions in the mornings and evenings at Panjgur and Pasni during successive days in July, there was a pronounced development of northerly winds at Panjgur between the 4th and the 12th and again from the 19th to the end of the month, though only in a feebler fashion. At the same time there was an abatement in the strength of the south-westerly monsoon winds at Pasni, and generally also at many of the coastal stations, the mornings being either calm or marked by northerly or easterly breezes and the south-westerly winds developing only in the afternoon. It is surmised that, in the absence of the south-westerly winds during July, the locusts present in the hinterland of Mekran had been carried in stages by the northerly winds into the coastal areas. The first entry of locusts into the Pasni area is probably referable to the development of northerly winds in the first fortnight of July, while the gradual addition to the population that was noticeable till the first week of August was the result of the north-westerly winds recorded at Panjgur in the latter part of July. In this connection, it may be recalled that in the case of the Seh-Gazan and Gar outbreaks it was reported by the local cultivators that the winged locusts had disappeared with the development of the 'Gorich' wind by the middle of July.

Wind direction recorded during July, 1935

Month & date	Wind Direction at			
	Panjgur		Pasni	
	8 A.M.	5 P.M.	8 A.M.	5 P.M.
July 1935				
1	N	W	CM	WSW
2	SSE	NNW	Cm	WSW
3	Cm	NNW	WNW	WSW
4	NNE	WSW	WNW	WSW
5	E	N	Cm	WSW
6	N	N	WNW	WSW
7	NW	N	Cm	SSE
8	N	NW	Cm	WSW
9	NW	N	W	WSW
10	SW	N	E	SSE
11	E	N	Cm	WSW
12	SSW	NW	Cm	SSW
13	W	S	Cm	SSW
14	SW	SW	WSW	WSW
15	SW	SW	WSW	SW
16	W	SW	WSW	SSW
17	SW	NE	WSW	WSW
18	W	SW	W	WSW
19	SSW	NW	WSW	WSW
20	W	NW	WSW	WSW
21	Cm	NW	WSW	WSW
22	Cm	N	Cm	SSW
23	W	NNW	Cm	WSW
24	W	WNW	WSW	WSW
25	NW	NNW	Cm	WSW
26	N	N	Cm	WSW
27	Cm	SW	ESE	SSW
28	WSW	NW	SSW	WSW
29	WSW	NW	WSW	WSW
30	Cm	W	Cm	S
31	Cm	NW	ESE	SSW

D. *Summer breeding*, 1935.—*Lasbela area and Mekran area.* Owing to the lack of summer rainfall, no summer breeding was noticed anywhere, except on the special areas on the Pasni reks. The breeding reported in the Seh-Gazan and Gar centres in the Panjgur area is really to be considered as a case of late spring, rather than as one of summer breeding. There is no doubt that heavy breeding might have resulted in the Lasbela area and in the interior of Mekran, if good rainfall had occurred.

Sind-Rajputana area. From 7 July, good rains were received in most parts of the desert, under the influence of a Bay depression, till the 16th, after which there was a drought till 15 August. During the third week of August, there was general rainfall in the desert, but it was, on the whole, light except at Bikaner (3.52 inches). An average of about 2½ inches was received in the Rajputana area, partly at the beginning and partly towards the middle of September, but there was little rainfall in the Thar area. There was complete drought during the monsoon period in south-west Sind, especially in the Karachi district.

1. *Thar-Mallani tract.* The first hopper of the season—recently hatched —was collected at Sil near Chachro on 28 July, indicating that oviposition had occurred about 14 or 15 July. The fact that a fifth stage hopper was noted on 10 August at Barmer would suggest an even earlier date of oviposition. With the commencement of rainfall, egg-laying would appear to have started immediately all over the area and had probably continued up to the beginning of August, after which it would appear to have ceased on account of the drying up of soil moisture. The first adult of the new generation was found on 29 August at Pasni in the Chachro area, and by the middle of September most of the locusts found in the desert were of the new generation. Hoppers were met with in good numbers during August and were present till the end of September. They were chiefly found on *Wekra* and *Bishani* and were all green in colour, and no black hoppers were seen anywhere by the survey staff, though it was rumoured that black hoppers had been found in the vicinity of Kantio by the end of July and that they had been destroyed by birds.

2. *Jaisalmer-Bikaner region.* At Sardarshahr, the first hopper of the season was noted on 4 August. It was a I-instar nymph, and it is obvious that egg-laying had started soon after rainfall in the second week of July. Both at Sardarshahr and at Nokh, few hoppers were met with and most of them were collected on *Aerua* (*Booh*) plants. On the whole, the breeding would appear to have been rather poor all over the area as only small numbers of hoppers were encountered by the staff. The first adult of the new generation was found at Sardarshahr on 29 August and at Nokh on 31 August. In August, a rumour was current at Nokh to the effect that oviposition by a swarm had occurred in July at Mohangarh (Jaisalmer) and that black hoppers had hatched. There was no confirmation of this report officially, nor did local enquiries made later on give support to it.

In the course of surveys carried out in the various parts of the Sind-Rajputana desert, it was apparent that a very large locust population was present spread all over the area, as also fairly high concentrations, varying in density from 1,000 to 5,000 per square mile, at certain places. It is probable that the incursion of migrants from the west, which began in July, was steadily continuing during the greater part of August, and that much of the locust population in the desert was also moving about from place to place under the influence of the prevailing weather conditions.

Considering, however, the large locust population present in the Sind-Rajputana desert areas during July and August, the breeding that actually ensued was apparently incommensurate with its size. Presumably this is attributable to the peculiarities in the distribution of rainfall, as well as to the state of maturity of the locusts at the time of rainfall. In July

when fairly heavy precipitation occurred in the desert, and the conditions of soil-moisture were optimum for oviposition, eggs were probably laid only by such individuals as had reached sexual maturity. The vast majority of the immigrant locusts were, however, apparently immature at that period, as evidenced by the possession of hyaline or pinkish hind-wings, but by the time they attained sexual maturity (about three weeks later), the soils had presumably become too dry for oviposition. The light rainfall that occurred in mid-August in parts of the area, amounting to an average of 1·50 inches, was evidently insufficient to favour any considerable breeding. Even in September, when a total fall of about 2½ inches was recorded in many places, conditions were not conducive, in general, for egg-laying, so that it only led to light breeding in parts of the desert.

IV. Autumn period, 1935.

(1) *Sind-Rajputana area.—September* 1935. Fair numbers of hoppers were met with during surveys in many parts of the desert, except in Jaisalmer-Nokh section where there was little breeding. Adults of the new generation were found in increasingly large numbers from the beginning of the month and replaced those of the old brood, which entirely disappeared by the end of September. A collection of 65 individuals in September from the Thar-Mallani area showed the facies: 63S:31T:6G: : 61(6):39(7), and of 94 specimens collected from different places in the northern part of the desert: 52S:31T:17G: :60(6):40(7). The new generation was found to be predominantly made up of *solitaria* individuals, and the *gregaria* component in the population was referable to the old brood.

With the fall of thunderstorm rain in many localities in the desert about the beginning and, later on, about the middle of September, light breeding had apparently been set on foot, for hoppers were noticed in some numbers in parts of the Thar-Mallani area, as well as in the Bikaner area during October; and even as late as the middle of November, three fifth-instar hoppers were found in the Chachro area. As some individuals of the new generation were found with fairly bright yellow wings by the middle of September, it is not unlikely that some of the hoppers noticed in October and November really represented the second generation of the monsoon.

October-November 1935. With the appearance of adults of the new generation, there was a rise in population density, (*vide* Statement V), both at Barmer and Chachro—being 2,174 and 3,619 per sq. mile respectively—during the first fortnight of September, but during the second, there was a considerable diminution in numbers, the density being 590 at Barmer and 1,074 at Chachro per sq. mile. In October, there was a further reduction of population at Barmer, followed by a gradual disappearance in November and December, while at Chachro there was a very considerable accretion of population during October, the average density being nearly 3,000 per sq. mile, although local breeding had practically come to an end. In November, however, there was a fall in numbers, the density being about 550 per sq. mile, and in December, only about 80 per sq. mile.

Similarly Nokh had an augmentation of population in October, followed by a considerable reduction in November and a complete disappearance after the 22nd November. On the other hand, at Sardarshahr a light rise in the population was noticeable in September as a result of local breeding, which was followed in October by a fall during the first fortnight and a complete disappearance from the 22nd. The increase of population at Chachro and Nokh as described above obviously indicates a progressive migration of locusts in a western direction during the autumn months.

Moreover, at Nokh a rather sudden rise in numbers was noticed between 15 and 23 October; further west, at Lathi and Choyan in Jaisalmer area, large concentrations of locusts were noted between 19 and 22

October; and good numbers were also met with between 26 and 28 October, between Sheo and Barmer. When these data are coupled with the fact of their disappearance from Sardarshahr from 22 October, they lead one to the inference that a general movement of locusts was probably afoot at that period in reaction to changes in the seasonal conditions.

In the Rajputana area, the monsoon withdrew from 20 September, and as a result there was a definite change in the meteorological conditions of the desert area, as may be seen from the following data extracted from the Monthly Review for 1935 of the Indian Meteorological Department.

Monthly Meteorological Data for August-December, 1935 in West Rajputana

Localities	Max. Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain
	Mean Max. in Degrees F.	Highest Max. in Degrees F.	Date	8 A.M.	5 P.M.	8 A.M.	5 P.M.		(Inches)
				Per cent.	Per cent.				
August 1935.									
Bikaner .	96·2	104	31-viii	67	43	SW; S; W	SW; S; SE	1·7	3·52
Jodhpur .	92·6	105	31-viii	70	46	SW; S; W	SW; S; SE	6·9	0·76
Barmer .	91·5	104	31-viii	72	50	SW; W; S	S; SW; SE	6·7	1·01
September 1935.									
Bikaner .	95·9	103	11-ix	67	38	SW; W; S	SW; S; E	2·5	2·48
Jodhpur .	93·1	99	1-ix	70	47	SW; W; NE	SW; Cm; E	5·0	2·89
Barmer .	92·5	100	1, 11-ix	72	46	SW; W; NW	SW; S; W	4·3	2·45
October 1935.									
Bikaner .	95·0	99	9, 10, 11-x	37	18	SW; SE; S	SW; W; SE; E	0·4	0·10
Jodhpur .	95·7	99	10-x	38	19	NE; Cm; SW	SW; Cm; NE	1·5	0·29
Barmer .	95·5	100	11-x	32	21	NW; Cm; N	SW; Cm; E	1·3	0·18
November 1935.									
Bikaner .	88·0	95	5-xi	38	17	SE; SW; Cm	W; NW; N	0·7	Nil
Jodhpur .	90·9	94	3, 5-xi	43	19	Cm; NE; N	Cm; SW; N	0·4	Nil
Barmer .	90·6	95	3, 10-xi	38	19	Cm; N; NW; SE	N; SW; Cm	0·7	Nil
December 1935.									
Bikaner .	76·8	88	5-xii	52	20	SE; E; NE	NE; NW; N	1·5	Nil
Jodhpur .	80·8	89	5-xii	43	25	NE; N	Cm; N; NE	2·3	Nil
Barmer .	80·3	90	1-xii	39	20	NW; N; Cm	NE; NW; N	1·9	Nil

It may be noticed from these data, that fairly high temperatures and comparatively low humidity were experienced in the Rajputana areas even in August and September owing to deficient rainfall. With the withdrawal of the monsoon by 20 September, cloudless skies accompanied by hot and dry weather prevailed during October and November. It is also seen that north-east winds commenced in the desert about 10 October and continued till the 26th, and thereafter with a few breaks throughout November and December. Records of wind movements made at Pasni Station for this period also closely correspond with these data. The development of the north-east winds in October and November may, therefore, be correlated with the movements of locusts in the Rajputana area noted above. In December the general fall of atmospheric temperatures would appear to have acted as a check on migration.

Biometrical analysis of population in October-November 1935

Area & month	Total number of specimens examined	Phase Proportion (in percentages)			Stripe Proportion (in percentages)	
		Solitaria	*Transiens*	*Gregaria*	6 Stripes	7 Stripes
Northern Desert.— (Jaisalmer-Bikaner)						
October 1935 . .	169	72	28	0	29	71
November 1935 .	31	55	42	3	28	72
Southern Desert— (Thar-Mallani)						
October 1935 . .	48	79	17	4	29	71
November 1935 .	40	78	20	2	30	70

The preponderance of forms with seven eye-stripes and of *solitaria* ratios and the almost complete disappearance of *gregaria* forms are noteworthy.

(2) *Lasbela area.*—As mentioned already, there was a decrease of population density during September on Ambagh-Sonmiani reks. The average for the month was 962 per sq. mile as compared with 2,108 in August. Neither pink nor yellow forms were seen on the reks, and almost all the specimens collected at this period had prominent body stripes with buff or cream alternating with dark mauvish brown. Most of them had brownish or smoky yellow hind-wings, and were evidently mature forms. A collection of 18 specimens made in September consisted of 2 *solitaria*, 6 *transiens* and 10 *gregaria* forms, and the biometrical index was: 11S:33T:56G: :94(6):6(7). The single specimen with 7 stripes was found to have pinkish-hyaline wings and was evidently a newly developed locust, presumably a migrant as there was no local breeding. The general facies was that of the incursion type with a preponderance of *gregaria* and six stripes.

There was a further reduction in numbers during the first fortnight of October, the average being only 295 per sq. mile, presumably by emigration westward with the prevailing north-easterly winds. During the later half of the month, there was a perceptible rise in the density, the average being about 440 per sq. mile, presumably due to the influx of forms with hyaline or very light yellow wings—evidently a recently fledged generation. During November, a still further rise in numbers was observable, the average for the month being about 660 per sq. mile. Out of 68 specimens collected from these reks between 17 October and 3 November, about thirty were of the new brood, the rest being the old 'incursion' forms, the following being the facies: 34S:37T:29G::74(6):26(7), in which individuals representing the new brood were characterised by a dominance of *solitaria* ratios. A collection of 22 specimens from the Lasbela area (including the Hingol reks) during December had the following facies: 59S:41T:0G::64(6):36(7), which showed that the population found in December was mostly a new brood, more or less akin to the monsoon generation produced in the Sind-Rajputana desert. The fact that a rise of population in the Lasbela area took place only in the latter half of October is significant, since locust movements were then set afoot in the Rajputana areas under the influence of north-easterly winds.

Locust Breeding. Owing to the failure of summer rains, there was no locust breeding in summer in the Lasbela area. On 5 October, however, a fifth instar hopper was collected from the Naka Kharrari Rek about 12 miles to the south of Ambagh which would probably indicate that stray oviposition had taken place in August following a light shower.

(3) *Mekran area.* With the exception of two specimens found in September at Shashtal and Siagisi, no locusts were seen anywhere in the interior of Mekran, whereas on the coastal plains, locusts were met with in most of the areas including Kulanch and Dasht throughout the autumn months.

As at Ambagh, it was found that on the coastal reks of Mekran, most of the immigrants had, by the middle of August, assumed typical *solitaria* coloration with mauvish brown stripes on a cream of yellow background. No individuals of the pink or yellow type were noticeable. In most places, however, a progressive decrease of population was noticeable from September to November. On the Pasni reks, the averabe density for September, October and November was 4,367,899 and 385 per sq. mile and in the Gwadar-Pishukan area, 5,548, 1,412 and 927 per sq. mile, respectively. In the Ormara area, the density was low during September and October, being 336 and 240 per sq. mile respectively, but in November there was a definite rise to 1,874 per sq. mile on account of the influx of hyaline-winged forms, presumably migrants from the Rajputana areas. At Pasni, forms with hyline wings were met with by the end of November, and were present in good numbers in December. At Gadar, such forms were apparently first found in December.

A biometrical examination of locust collections made between September and December in the Mekran coastal areas gave the following results:

Biometrical analysis of locusts found on the Mekran coast, September-December 1935

Month and area	Total number examined	Phase Proportions in percentages			Stripes Proportions in percentages	
		Solitaria	*Transiens*	*Gregaria*	Stripes	Stripes
1	2	3	4	5	6	7
September 1935.						
Kulanch-Dasht .	36	20	37	43	89	11
Pasni Reks . .	23	26	48	26	95	5
October 1935.						
Pasni-Ormara areas .	42	36	36	28	83	17
November 1935.						
Pasni Reks . .	40	72	23	5	57	43
Ormara Reks . .	66	54	29	17	62	38
Gwadar Reks . .	19	10	53	37	93	7
December 1935.						
Kulanch area .	25	76	20	4	40	60
Pasni Reks . .	44	66	25	9	52	48
Gwadar Reks .	22	36	32	32	68	32

The results clearly indicate that the locusts found in September and October in Kulanch-Dasht, Pasni and Ormara were of the incursion type, with a preponderance of *gregaria* and 6-striped forms. In November, the populations on the Pasni and Ormara reks show an increase in the proportions of the *solitaria* and 7-striped forms and a decrease of *gregaria*, presumably by reason of the influx of a new brood, whereas at Gwadar the facies is still of the 'incursion' type. In December, there is a greater approximation to the type found in the autumn months in Rajputana, in the case of Kulanch and Pasni areas whereas at Gwadar the percentage of *solitaria* and 7-striped forms has risen, indicating that an infiltration of the new brood was taking place.

These data lead one to the inference that a westward migration was obviously in progress during the months of November and December in the Mekran coastal areas, the population of the 'incursion' type shifting further west and being gradually replaced by one of the 'desert' type.

Mauve colour of the wings. The development of a distinct mauve tinge at the base of the wings first attracted the writer's notice, while examining the specimens collected at Ormara and Pasni in October. Though the wings were brownish yellow, indicating that they were of the old generation, their wing-bases had a bright bluish mauve tinge, which was in striking contrast with the smoky yellow of the rest of the wing. Subsequent observations showed that many of the hyaline-winged forms of the new brood appearing on the Ambagh and Pasni reks in November and December also had such a mauve tinge at the wing base. Experiments carried out later on in 1936 and 1937 proved that the development of mauve tinge on the wings was the result of the action of sunlight on the wings during flight, so that the presence of mauve or pink colour may generally be taken to be an indication of migration.

Summary of the data for 1935

The year 1935 proved to be an eventful one from the point of view of locust research.

The winter rainfall proved to be early and heavy in the Baluchistan areas, and the scanty locust population—made up of migrants from the Sind-Rajputana desert—bred on the coastal reks. Adult locusts of the new brood appeared by the end of March, especially on the Gwadar-Pishukan reks. A migration of the new brood into the valleys of the Mekran hinterland occurred in April-May. It was rather noteworthy that the new brood contained an appreciable proportion of *gregaria* forms.

As a result of adequate rainfall in the interior in April, crowded breeding occurred in favourable localities in parts of Mekran and Kharan and led to the formation of incipient swarms, as for instance at Shashtal, Gar, Seh-Gazan and Washuk. It is possible that such "outbreak centres" had also come into existence in other parts of Mekran without being reported, and that incipient outbreaks had likewise occurred in similar circumstances in Iranian Mekran and in Oman.

In July a widespread incursion of locust individuals was detected by the survey staff (1) along the Mekran and Lasbela coasts, (2) in the desert areas of Rajputana, and (3) in the plains of Sind and Kachhi. It apparently took the form of light swarms in the Khairpur, Jaisalmer and Bahawalpur areas. The 'incursion' population was distinguished biometrically by the preponderance of forms with *gregaria* and *transiens* ratios and with six eye-stripes. It is presumed that this incursion had probably originated in regions of winter rainfall in the west from outbreak centres of the type noted in the interior of Mekran in May, June

STATEMENT V. *Results of Locust Surveys, 1935*

The figures represent the average population per square mile for the whole month in the areas surveyed and 'H' indicates occurrence of breeding

Seasons	Months	MEKRAN							LASBELA		SIND-RAJPUTANA DESERT									
		Gwadar Pishukan	Pasni (Int. surveys)	Ormara	Kech	Panjgur	Kulanch-asht	Kolwa	Hingol	Ambagh (Int. surveys)	Hinidan Bela	W. Sind & Kachhi	S. W. Punjab Bahawalpur	Chachro (Int. surveys)	Barmer (Int. surveys)	Thar-Mallani	B. Jaisalmer W. Bikaner	Nokh (Int. surveys)	E. Bikaner	Sardar Shahar (Int. surveys)
Winter	Dec 1934	26	18			Nil				19	Nil	Nil	Nil	Nil	Nil	Nil	34			Nil
	Jan. 1935	160	19			Nil	Nil			Nil			Nil	Nil		Nil	Nil			Nil
	Feb. 1935	31	84			Nil		Nil	23	4		Nil		Nil		Nil	34			Nil
Spring	March 1935	H 30	H 22	29	14	Nil			12	Nil		Nil		Nil		Nil	Nil		19	Nil
	April 1935	H 114	H 226	H 328		111	H 338	130		4	Nil			Nil	Nil	Nil	Nil			Nil
	May 1935	214	H 370	H 1031	H 240		H 1100		64	4	Nil		H Nil	12	Nil	2		3		Nil
Summer	June 1935	175	H 218		H 6027		H 141	Nil	112	105				8	18	14		158		10
	July 1935	1661	H 6957	3013	660		993			5306	2048	3961		3159	H 1029	H 2478	694	592		104
	Aug. 1935	8913	H 8868	3413	96	407	912	40	1328	2108				H 1861	H 3702	H 601	436	240	48	H 15
Autumn	Sept. 1935	5548	H 4367	336	14		728			962	45			H 1585	H 654	H 247	68	H 326	7	H 79
	Oct. 1935	1412	H 899	240	Nil		565			H 378			9 (Khairpur)	H 2990	482	H 368	271	471		H 28
	Nov. 1935	927	H 385	1874	9		109		668	661				H 556	32	H 23	47	139	13	Nil

and July at Shashtal, Gar and Seh-Gazan. With the development of dry, hot winds in June and July, it is probable that the locusts had been obliged to leave the western regions and to drift with the prevailing winds into the Indian area. While the south-west winds, which generally prevail in May, June and July, would normally carry them into Upper Sind and the northern parts of the desert, the occurrence of abnormal northerly winds in the Panjgur-Turbat area, as had developed in the first week of July, 1935, would take them into the coastal areas.

There was good monsoon rainfall in the first fortnight of July in the Sind-Rajputana desert area, and all such individuals as had reached sex-maturity laid eggs, and hoppers were found in many parts of the desert in August and September. As drought prevailed for about a month from 16 July, and as the rainfall in August and September was much below the average, the extent of breeding in the desert during the monsoon period was not commensurate with the vast numbers of locusts found after the incursion.

With the withdrawal of the monsoon on 20 September, dry weather set in. As during October and November, there was, in addition, a rise in temperature, locusts were observed to leave the desert area, and with the development of north-easterly winds, found reaching the Ambagh reks in October, the Ormara-Pasni areas in November, and Gwadar in December.

There being no summer breeding in the Lasbela area on account of the failure of monsoon rainfall, the occurrence of individuals of a recently fledged brood in good numbers in the Ambagh area in October-November is convincing evidence of the occurrence of long-distance migration among the solitary locusts. The population found in autumn in the Rajputana desert was characterised by the preponderance of *solitaria* forms and of individuals with seven eye-stripes, and the almost complete absence of *gregaria* ratios. The forms of the new generation found appearing in October-November in the Lasbela and Mekran areas were also distinguished by these biometrical characters.

In 1926, a similar multiplication had occurred in the winter rain areas as a result of good winter rainfall, and a similar incursion would appear to have occurred in July 1926, but as the monsoon rains were unusually heavy and there was well-distributed rainfall in the months of August and September, heavy and continuous breeding occurred in the desert which brought the last cycle of 1926—31 into existence. A similar cycle might have been inaugurated in 1935, if there had been heavy rainfall during the months of August and September in the desert.

CHAPTER V

Year 1936

Weather notes for 1936

Winter rainfall 1935-36. The first western disturbance of the winter season of 1935-36 made its appearance on 8 October 1935, and the last one during the fourth week of May 1936. Altogether about fifty-three disturbances were recorded during the season.

During December, 1935, there was little rainfall anywhere, except in the Bushire region of the Persian Gulf. In January 1936, there was fairly good rainfall during the earlier half of the month, Muscat recording 5·63 in., Sharjah 1·89 in., Pasni, Ormara and Jask about 1·5 in. each and Gwadar 0·5. The latter part of January and the first fortnight of February proved to be a dry period, the disturbances resulting only in dust-storms. During the last ten days of February, fairly good rainfall occurred along the coast and in the interior of Mekran, under the influence of two depressions. Further rainfall was received during the first fortnight of Mekran, especially at Gwadar, Turbat and Panjgur. There was little rain after this period, except for 0·53 in. on the 19th May at Panjgur. The total winter rainfall was about four to five inches, on the whole, in the western areas, and was below the average.

There was little winter rain in the Indian Desert, except in February when a few good falls occurred in the Jaisalmer-Bikaner areas.

Monthly Rainfall Data for Winter-Spring Season, 1935-36.

Localities	Nov. 35	Dec. 35	Jan. 36	Feb. 36	March 36	April 36	May 36
Iran							
Jask	..	0·31	1·60	0·05	0·06	..	..
Charbar	..	..	1·80	0·05	1·91	..	..
East Arabia.							
Muscat	..	..	5·63	0·22	1·09	..	..
Sharjah	..	0·16	1·89	0·02	0·07	0·11	..
Baluchistan.							
Pasni	..	0·32	1·65	0·38	0·90	..	..
Gwadar	..	0·31	0·62	0·60	2·70	..	..
Ormara	..	..	1·86	2·52	0·84	..	..
Turbat	..	..	0·97	0·58	1·61	..	..
Panjgur	..	..	1·07	0·95	1·46	..	0·53
Gandhawa	..	..	0·08	0·89	0·35	..	..
Sibi	..	..	0·11	2·33	0·41	..	..
Quetta	..	0·16	1·97	3·43	0·70	0·19	1·21

Monsoon Rainfall 1936

The south-west monsoon set in very early both in the Arabian Sea and the Bay of Bengal by 19 May. The formation of a depression early in May at the head of the Bay brought heavy rainfall into the eastern parts of North India, but its influence did not extend westwards beyond eastern Rajputana. Between 20 and 26 June, widespread thunderstrom rain occurred in parts of Rajputana, Punjab and South Sind, Bikaner and Jodhpur receiving about 2 inches each. A depression, which appeared over the Central Provinces on the 28th, passed rapidly across Rajputana into South Sind, and caused general rainfall at the end of June and the beginning of July at various places: Badin 10 in., Karachi 3 in., Chachro 3·60 in., Mithi 3 in., Barmer 2 in., Jodhpur and Bikaner about 2 in. each, Bahawalpur 2 in., and Lasbela 1 in. The influence of the depression was

felt in July also in the interior of Mekran, Panjgur recording 1·40 in. and Turbat 0·80 in. With the exception of a few falls in Bahawalpur and Upper Sind about the middle of July, there was no rainfall in the desert areas till the second week of August. A depression that passed over north Rajputana north-westwards in the direction of Bahawalpur and Multan between 12 and 16 August occasioned very heavy rainfall in parts of Bikaner and Jaisalmer, the heaviest falls being in the area situated between Bikaner, Nokh and Phalodi. There was further fairly widespread rainfall between 19 and 23 August in the areas of western Rajputana. On the whole, a total fall of 16 inches was recorded at Nokh during August, 13 inches at Bikaner, Bap and Surpara, 15 in. at Sri Kolayatji, 11 in. at Sri Dungargarh, 9 in. at Sujangarh, 10 in. at Phalodi and 8 in. at Ratangarh. Rainfall was much lighter in other parts of the desert. Jodhpur receiving only 2 in., Barmer 1½ in. and Sardarshahr 3 in. In September, a depression from Central India moved north-westwards across south Rajputana between the 8th and the 13th and caused fairly widespread rainfall in the southern areas of Rajputana and Sind. in south-west Punjab and in eastern Baluchistan, Multan recording 4 in., Bahawalpur 1·5 in., Khanpur 1 in., Badin 3 in., Chhor 2 in., Chachro 1·25 in., Barmer 1 5 in. and Jodhpur 1·60 in. Widespread thunderstorm 2 in., Sibi 0·5 in. Baluchistan on 16 and 17 September, Lasbela receiving 2 in., Sibi 0·5 in. and Kalat 0·25 in. The monsoon began to withdraw from the country about 19 September.

Between 13 and 16 November, some rainfall occurred in parts of Sind and Rajputana under the influence of a cyclonic storm passing from the south-eastern part of the Arabian Sea northwards into the Kathiawar coast.

Monthly Rainfall Data for the Monsoon Period 1936

Localities	May	June	July	August	September
Rajputana Area.					
Bikaner	..	..	0·79	13·27	0·61
Sardarshahr	..	0·63	0·48	2·93	0·30
Nohar	..	0·61	1·02	6·54	0·93
Surpura	..	..	2·23	13·83	1·29
Ratangarh	0·04	1·66	0·72	8·00	4·00
Jaisalmer	...	1·36	3·24	0·22	0·21
Nokh	..	..	0·60	16·27	0·60
Bap	..	1·33	0·60	13·07	2·46
Phalodi	..	0·87	0·54	10·28	0·77
Jodhpur	..	3·59	2·04	2·38	1·65
Barmer	..	0·99	2·97	1·30	1·65
Sind Area.					
Chachro	..	0·34	4·64	0·06	1·25
Karachi	..	0·72	2·64	0·01	0·03
Jacobabad	..	0·03	2·67	..	..

Localities	May	June	July	August	September
South Punjab.					
Hissar	0·16	2·31	2·47	1·25	0·98
Dera Ghazi Khan . . .	..	0·44	5·09	1·26	2·41
Bahawalpur	..	1·18	3·02	2·54	1·36
Baluchistan area					
Gandhawa . .		..	1·60	..	..
Sibi . . .	..	0·07	0·37	..	..
Bela	0·01	0·07	1·13	..	..
Ambagh	..	0·38	1·32	..	..
Ormara	..	..	0·10	..	..
Pasni	..	..	0·07	..	..
Panjgur	0·53	..	1·40	..	..
Turbat	..	..	0·80	..	..

It is seen from the above data that rainfall was greatly in defect in Lasbela and Mekran in summer, and that heavy rainfall was restricted to the northern parts of the desert.

Observations on Locust Distribution during 1936 (*vide Statement VI*)

I. Winter period 1935-36

Sind-Rajputana areas. Few locusts were met with in winter except in the Chachro and East Jaisalmer areas.

In the north, a few locusts were found around Sardarshahr during December 1935, as also a few near Bijnot along the Jaisalmer-Bhawalpur borders. During January only one specimen was found at Nokh on the 24th. During February, however, fairly good numbers were observed. A few locusts were found at Nokh and Sardarshahr, and fairly good concentrations between Mohangarh and Basanpir on the 18th and the 19th (about 1,000 per square mile), as well as several scattered locusts at other places. The population noted near Mohangarh is probably to be correlated with a sharp shower amounting to half an inch on 17 February. and since one hopper was met with here in April, it is presumed that light breeding had followed.

32 specimens of this period from the Mohangarh, Basanpir and Nokh areas had the following facies: 69S:31T:0G::30(6):70(7-8). It should be mentioned that out of 32 specimens examined, one from Jasurana near Basanpir (18 February) had *eight* eye-stripes, but has been grouped for the sake of convenience with the seven-striped forms. Most had light yellow or hyaline wings, and a good many exhibited a pinkish or mauve tinge at the base, indicative of migration. As the biometrical characters of February were practically the same as those of November 1935 in this area, it is obvious that the population had been over-wintering here.

In the southern parts, no locusts were met with during December, January and February, in South Jaisalmer and Mallani, except for a single specimen collected at the Baitu on 19 December. On the other hand, a

fairly good locust population was noticeable in the neighbourhood of Chachro throughout winter as also in the area between Chachro and Gadra. The density at Chachro ranged between 100 and 500 per sq. mile. The biometrical characters based on 37 specimens, were: 86S:11T:3G::41(6):59(7), a facies similar to that of the November population.

Many of the specimens collected near Chachro during February and March showed the presence of green algae on the hind wings (Rao—1941); an indication that they had been living in a rather cool and moisture-laden atmosphere for some considerable time. Out of several marked locusts liberated in November, 1935, in the vicinity of Chachro, three specimens were recovered —one on 5 December, another on the 20th and a third on 8 March 1936, which indicates that during winter there is not much of migration. This shows that locusts had been over-wintering in the Chachro area during winter 1935-36, unlike the previous year.

Lasbela area. As contrasted with the previous year, good numbers of locusts were found in the winter of 1935-36 in the Lasbela rek areas. The average population (See Statement VI) was about 255 per square mile for December, 1935, about 100 for January 1936, and about 181 for February, 1936. A considerable amount of fluctuation in density was observable during this period, especially in the latter part of January and the occasional rises in the population were presumably due to influxes of migrant locusts associated with easterly winds. Fair numbers were also met with in the Hingol areas during December and February. Many of them had pinkish or mauve wings, and by February a good number had developed light yellow wings, presumably as a result of an inch of rain in February.

60 specimens collected on the Ambagh-Naka Kharrari reks during the winter period had the following facies: 52S:40T:8G::57(6):43(7). The population was, thus, in the main, of the type produced in the Rajputana desert, the *gregaria* components being referable to individuals of the 'incursion' type still left in the area. Twelve of them had *green algae* on the wings.

Mekran area. A fairly high locust population was found scattered over the reks of Mekran during winter. It was made up, in part, of locusts of the 'incursion' type with high biometrical ratios, six-striped eyes and yellowish brown wings, and, in part, of individuals of the 'desert' type—with *solitaria* ratios and hyaline or mauve wings. An analysis of 357 specimens from the Gwadar, Pishukan, Pasni and Ormara reks during December, January and February indicated the following characters: 52S:36T:12G::63(6):37(7).

In the interior of Mekran, a fairly dense population was noticed in Kulanch and Dasht, and a small number in the Kech valley, but no information is available for Kolwa and Panjgur. 40 locusts from the Kech, Kulanch and Dasht areas had the facies: 70S:28T:2G::40(6):60(7). On the whole, fewer individuals of the 'incursion' type were noted in the interior areas. Green algae were found on old forms from Kulanch.

II. Spring period—1936

(a) *Sind-Rajputana areas.—The Northern areas.* With the exception of two locusts at Nokh on 6 and 17 March, none were noticeable at Nokh and Sardarshahr. One locust was found on 16 March between Charanwala and Barsilpur and another on 9 April near Bap. The area between Mohangarh and Basanpir, where a locust concentration was noted in February, was examined during the latter part of April. A fourth-stage hopper was found on *Booh—Aerua tomentosa* between Tarana and

Mohangarh on the 22nd, indicating light breeding, as also a single female locust with light yellow wings, six-striped eyes and E/F ratio—2·12, near Mohangarh. As the specimen had green algae on the wings, it was presumably derived from a southern source, since locusts carrying algal growths were known to be present in the Chachro area in February-March and were found disappearing from there in April. No locusts were met with in May, except for one *solitaria* female (E/F 1·96) with 7-striped eyes, with mauve wings, collected at Nokh on 31. May—possibly the first migrant of summer.

The Dera Ghazi Khan area. Five green hoppers were found on *Booh* (4 to 6 May) near Dera Ghazi Khan, as also a single locust with light yellow wings. As several hoppers were noted here in April, some amount of breeding had apparently taken place in the wake of winter rainfall (about 2·37 in. in January-March).

The Southern areas. No locusts were met with in Thar-Mallani, except in the Chachro-Gadra tract during March, April and May. At Chachro, about 40 specimens were found of which 23 collected during March had the following facies: 86S : 14T : 0G : : 67(6) : 33(7) —evidently the over-wintered generation of the autumn of 1935. Many specimens had algal growths on the wings. Outside Chachro, only one locust was noticed at Gadra on 7 March. In April, there was a perceptible diminution of population at Chachro, and a small batch of eight specimens collected at Chachro possessed *solitaria* ratios and six-striped eyes. As the wings were either hyaline or light yellow with mauve at the base and as algal growths were absent, it is surmised that they were migrants from outside. In May, except for a specimen collected on the 2nd at Chachro, no locusts were seen till the 15th, when a *solitaria* male (E/F 2·00) was captured, and later on eight more locusts, with a facies: 78S : 22T : 0G : : 37(6) : 63(7). All had light yellow wings with mauve or pink base, and probably represented the earliest batch of migrants from the Mekran areas.

(b) *The Lasbela area* Fair numbers were noticed during March, the average density for the month being about 99 per sq. mile. A decrease was noticeable towards the end of March, which was further accentuated during April, the average being only about 19 per sq. mile. As a result of about an inch of rainfall in February, many locusts developed deep yellow colour in the wings, and a few were also observed pairing. Nevertheless, there was apparently no breeding in the Ambagh area. On the other hand, a second-stage hopper was noted on *'Kullichk'—Cyperus arenarius*, at Khandewari in the Hingol area on 29 April, indicating that some light spring breeding had occurred in the western areas, though at the time of the visit very few adult locusts were to be observed in that area.

An increase in population was observed at Ambagh by the middle of May, and after the 27th, a perceptibly high rise was noticeable. A good many of the specimens carried red mites on their wings and showed a tinge of pink or mauve at their wingbases. Most of the locusts, moreover, were cream-yellow in colour with bluish brown stripes. As a similar rise of population was noticed also at Pasni, it may be considered to be part of the usual summer migratory movement. An analysis of a small collection made at this period indicated the facies: 17S : 75T : 8G : : 73(6) : 27(7).

(c) *The Mekran area.*—1. *The Mekran reks.* Locusts were numerous on all the Mekran rek areas during March and density varied from 100 to 200 per sq. mile. An analysis of 113 specimens found on the different

reks showed the following index: 51S:36T:13G::45(6):55(7). A few of the 'incursion' forms were found till the last week of the month, after which none were met with. Since it may be assumed, that most of the individuals of the 'incursion period' had acquired wings either by the end of June or early in July, 1935, the last specimens noted at the end of March should be considered to have been over 8 months old.

Spring breeding. At Pasni, the first good shower was received on 9 January (1·32 in.), and the next one on 22 February (0·80 in.) and the last fall of the season (0·80 in.) was on 6 March. The total fall for winter amounted to about 3·5 in., much below the average (7 inches). At Gwadar, the rainfall was much lighter in January and February, but there was a heavy fall of 2·50 in. on 6 March. At Ormara. the rainfall was comparatively heavier and totalled over 5 inches. Everywhere, however, rainfall was in deficit.

Following the first heavy showers, it is surmised that the first egg-laying had occurred at Pasni at the end of January. The first hoppers of the season were detected on 21 March and were of the I and II instars. The first adult of the season was found on 18 April, and it is, therefore, likely that the earliest hatching had taken place at the end of February or the beginning of March. As the rainfall was light and the intervals between the individual falls were long, conditions were not favourable either for extensive or prolonged egg-laying. Breeding was, on the whole, confined to the special areas at Pasni, and after 18 May, no hopper was met with even on these. Similarly none was seen on the Gwadar and Ormara reks after the third week of May.

During May the locusts found were mostly of the new generation in all the reks. During the first fortnight the average density on the Pasni Reks was about 74 per sq. mile, but by the end of the month, it had risen to about 136, the rise being due to the sudden appearance of rather strikingly coloured individuals from 28 May onwards. They had bluish brown body stripes and patches of pink or mauve at wing base. Many of them, moreover, carried red mites on the wings. A similar increment of population was noted at Gwadar on the 26th, and good numbers of such individuals were found on the Ormara reks by the middle of June. It was reported by the Naib that large numbers of locusts had been noticed, in the vicinity of Ormara on 2 June, (*vide* Table VII). A biometrical examination of the locust collections on the Mekran reks in April and May showed that the population found during April-May till May, 26, was noticed to be more or less homogeneous, and an analysis of 62 specimens indicated the facies: 64S:31T:5G::56(6):44(7). A collection of 54 locusts captured between 26 and 30 May at Pasni and Gwadar had the following characters 20S:76T:4G::87(6):13(7). The main feature of the new migrants was thus a predominance of *transiens* and six-stripes. It may be recalled that Ambagh also, recorded at this period, migrants with a similar facies: 17S:75T:8G::73(6):27(7).

2. *The Mekran hinterland.* Fairly good rainfall was received in the interior of Mekran in winter and spring, the falls recorded in January, February, March, April and May being at Turbat 0·97 in., 0·58 in., 1·61 in., nil and nil, and at Panjgur 1·07 in., 0·95 in., 1·46 in., nil and 0·53 in., respectively. Exact figures are not available for the Kulanch-Dasht areas, but it was ascertained that rainfall was fairly satisfactory in Kulanch, but was defective in the Dasht valley.

Spring breeding. In the Kulanch-Dasht areas, fair numbers of locusts were met with in March, the density varying from about 70 to 130. A

collection of 17 specimens analysed as follows: 65S:35T:0G: : 47(6) : 53(7). On 20 March, several green hoppers. (I, II and III instars) were found on '*Marrand*' in a cultivated field at Kandasole, and on the 31st, at Kandasole 111 hoppers were collected mostly on thick patches of *Marrand* growing on the sides of an embankment in a field of '*Arzu*'—(*Panicum miliare*). They included individuals of all instars and were mostly green, except for nine which were of the intermediate type, with brown patches. The Black-headed Bunting—(*Emberiza melanocephala*) locally known as Zarichk was present in numbers and observed picking the hoppers off the bushes.

Hoppers were being met with in small numbers throughout April in Kulanch at Nokbur, Ban and Kandasole, both on *Marrand* (*Heliotropium*) and *Kapocham* (*Chrozophora*) in fields as well as on dry beds of watercourses. Some of the hoppers were of buff colour with brownish patches and possibly represented the *transiens* phase. No hoppers were met with in Kulanch after third week of May. In the Dasht area, small numbers of hoppers were noted only at Suntsar and Shooli. The adults began to appear by the middle of April, and by the middle of May, the old generation had mostly disappeared. The biometrical index of 14 specimens of the new brood collected in these areas was 64S : 29T : 7G : : 93(6) : 7(7).

In the Kech Valley, small numbers of locusts were met with during March and early in April, after which few were noticed till the later part of May, when one locust was collected in the Nodez area, and two between Wakai and Purchinan in the Zamuran area, and apparently no spring breeding occurred.

Fairly good numbers of scattered locusts were met with all over Kolwa in March, and the facies of 11 preserved specimens was 82S : 18T : 0G : : 44(6) : 56(7), which indicated their affinities to the autumn migrants from the 'desert'. Unfortunately this area was not visited again till June, but enquiries then made elicited the information that hoppers of the *gregaria* type had appeared on a young *jowar* crop at Rodkan by the end of March and had caused some damage to the crop in April. The local inhabitants reported that after rainfall at the end of February and the beginning of March, brownish locusts were noticed flying about and pairing in the field, and that black hoppers hatched out later on. The hoppers are said to have ultimately turned into pinkish adults, which had flown away within about a week of getting wings.

This should apparently be considered as a case of incipient outbreak, and the parent locust—as indicated by the biometrical index of the specimens collected in March—were evidently derived from the overwintered generation known to have been present in Kulanch and on the coastal reks in January and February. It is presumed that, deficiency of rainfall on the coast had caused them to migrate into the interior, possibly along with the comparatively warm westerly winds associated with winter disturbances.

In June, seven locusts were observed in the Rodkan—Chambar-Kalat areas, and an examination of two specimens preserved showed that one of them was a 7-striped form with *solitaria* ratios and pinkish wings and the other a 6-striped one with *transiens* ratios (2 : 15) and yellowish wings. Possibly these represented the new generation appearing in Mekran in summer. In the Panjgur area, little information is available except that a few locusts were seen at the end of March.

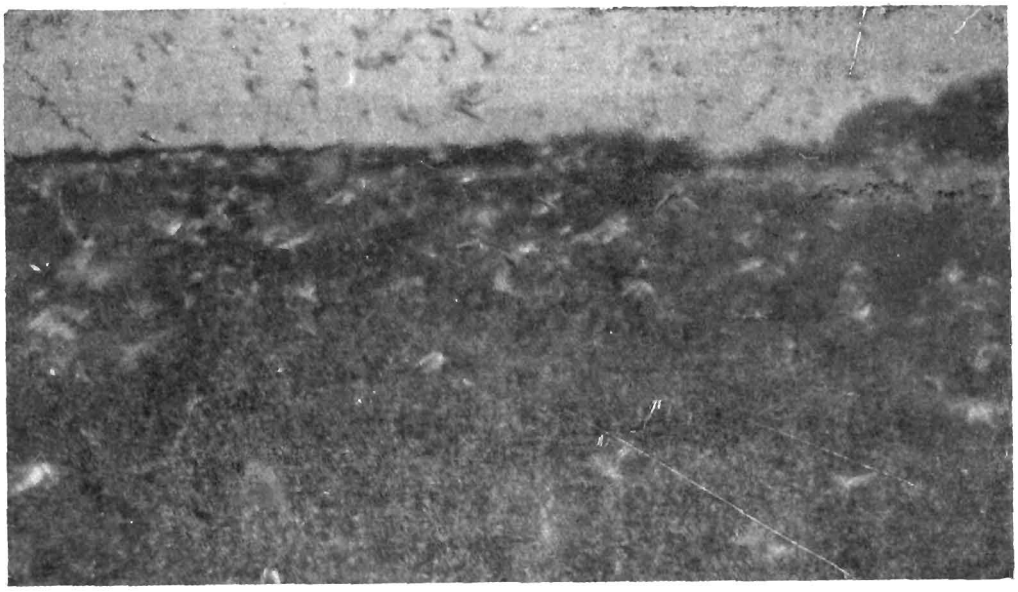


Plate 14.—*Pink locust swarms at Quetta* : Pink locusts were found visiting a lucerne field near Quetta in July 1931. The field was badly damaged.

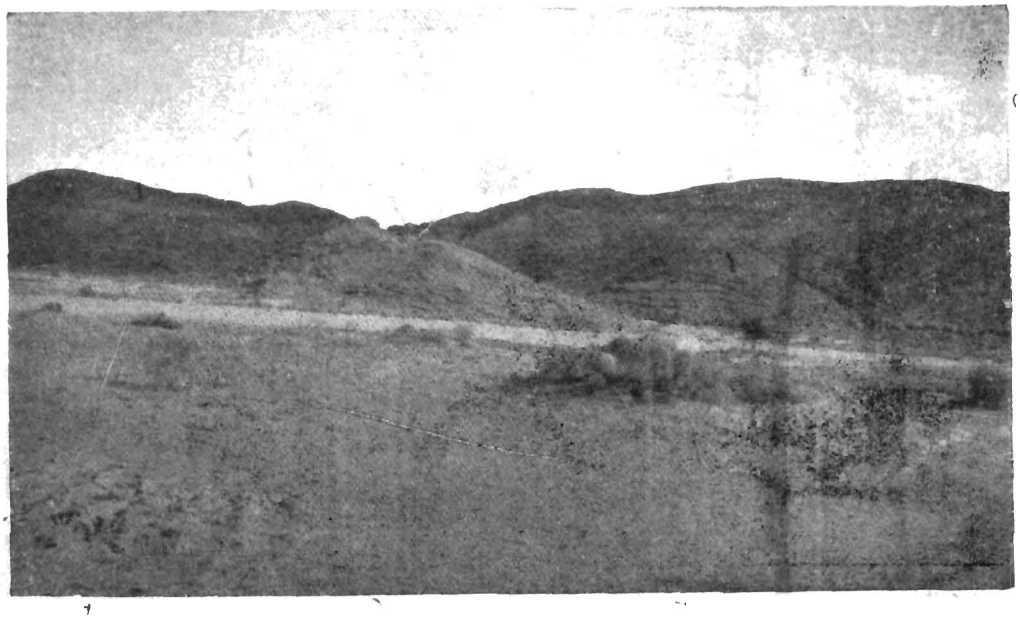


Plate 15.—*Shashtal rek near Nasirabad in Kech valley* : Photograph (February 1936) of actual site of the outbreak centre reported in May-June 1935. Large bands of incipient swarms of hoppers were said to have been seen here.

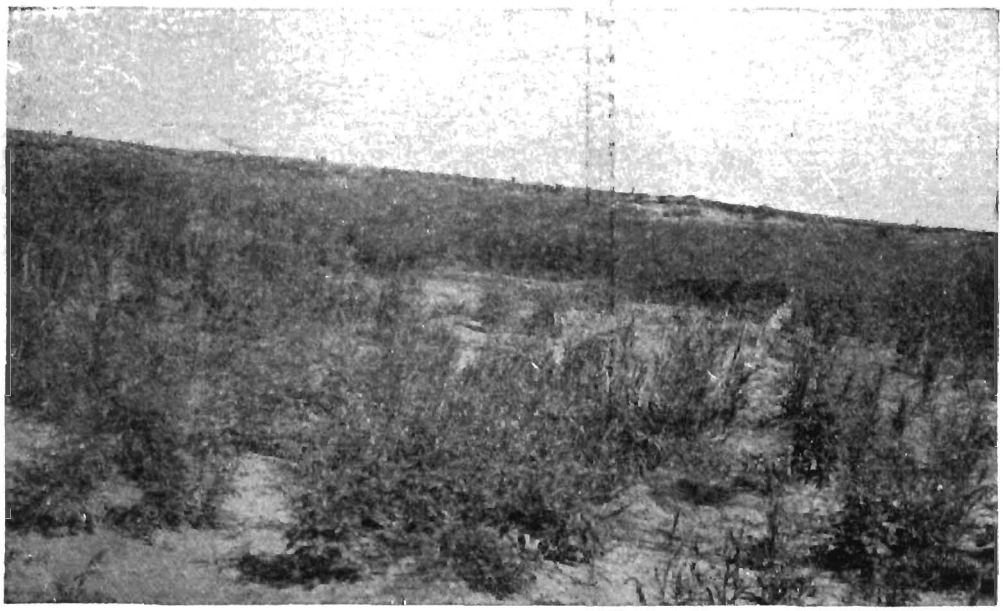


Plate 16.—*A patch of cultivation in the desert*—September, 1936 ; Bikaner State ; mostly Bajri (*Pennisetum typhoideum*), Til (*Sesamum indicum*) and Guar (*Cyamopsis psoralioides*). Hoppers and adults of the desert locusts were found in fair numbers here.

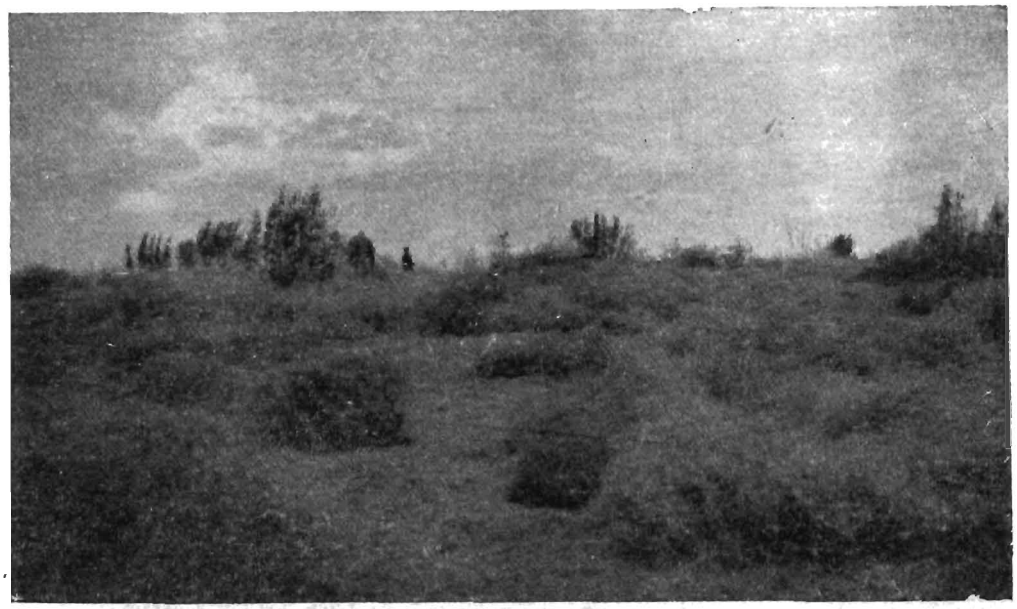


Plate 17.—Rank growth of Chag (*Crotalaria burhia*) and grass (*Panicum spp.*) seen in February, 1937 near Nokh, owing to the heavy rains of August, 1936. Locusts over wintered at the base of these bushes in these places.

III. Summer period, 1936

The Mekran area.—The Mekran reks. During June, the light immigration of locusts, noticed since 26 May, continued, and the average population on the Gwadar, Pasni and Ormara reks was between 150 and 350 per square mile. However, the numbers soon began to decrease, and by the middle of July, the density was as low as about 50 per sq. mile. During August also, there were few locusts to be seen. A collection of 138 locusts captured on the Mekran reks during June had the following biometrical index: 57S:38T:5G: 61(6):39(7). A batch of 54 specimens collected in July analysed as follows: 49S:51T:0G:O:57(6): 43(7), and another of 42 specimens in August: 40S:55T:5G::71(6):29(7).

As there was no summer rainfall on the rek areas of Mekran, no breeding was observable anywhere.

The Mekran hinterland. No locusts were met with in the Kulanch-Dasht area during June, July and August, nor in the Kech or Panjgur Valleys. In spite of the fall of 0·80 in. at Turbat and 1·40 in. at Panjgur in July, no breeding was noticed. On 25 June, about 65 hoppers of green colour were found at Nigor Kan Daf, 5 miles south of Thana Daragh in the Panjgur area. They were all collected from *Kapocham* plants (*Chrozophora*) in a jowar field, and were of I to III stages. It is presumed that oviposition had occurred in the latter half of May, following thunderstorm rain on 19 May in this area, 0·53 in. being recorded at Panjgur, and should be considered to represent the second generation of the spring season, analogous to the breeding recorded at Seh-Gazan and Gar in 1935. In a year of good rainfall, this place might have doubtless, functioned as an 'outbreak centre'. The Survey Assistant visited this locality a fortnight later and found several hoppers of the III and IV stages.

In Kolwa, though in mid-June seven locusts had been seen in the Rodkan area, none was observed in the middle of July. In August, 4 locusts were encountered between Rodkan and Hoshap on the 9th of which one was reported to have had transparent wings, indicating recent breeding. As such hyaline-winged specimens had also been met with in August in Ormara and Gwadar areas, it is presumed that light summer breeding had occurred in plants of the Mekran hinterland, in view of the general fall of rain in July.

The Lasbela area. As already noted, an increase in population was observable on the rek areas from 27 May, In June, the rise in the density apparently, continued, and the average for the month was 253 per sq. mile. As for the Mekran reks, a district fall in the population was observed in July and August, the averages being 63 and 32 per sq. mile respectively. Even as regards the biometrical characters, the changes observed during the months of June, July and August were roughly parallel in both areas, as may be seen from the following analysis for Ambagh rek areas:—

June: 90 specimens: 60S: 34T:6G: :60(6):40(7).

July: 24 specimens: 45S:55T:0G: : 63(6):37(7).

August: 14 specimens: 71S:29T:0G: :78(6):22(7).

Summer breeding. At Ambagh precipitation amounting to 0·38 in. was recorded on 24 and 25 June, and on 1 July the only heavy fall of the season—1·05 in.—was received, followed by light showers on three days. The total rain for July was 1·32 in., and for the monsoon season 1·70 in. Light breeding occurred on the reks during July and August. Hoppers

were found only in small numbers, and the first adult of the season was collected on 14 August, indicating that egg-laying had occurred soon after the first heavy fall on 1 July. Fairly good breeding was observed also in the Goth Sher Khan area.

On the Hingol reks, forms of the May incursion type were noted in June; but none was seen during the next visit in August, and no breeding was observable.

Sind-Rajputana area.—Southern area. Few locusts were noticeable on the whole, during April and May, except around Chachro, where as already mentioned, a few locusts began to appear during the latter part of May. In June, however, a good number were found, the average density being about 91 per sq. mile. Most of them had light yellow or yellow wings with mauve bases. A collection of 23 specimens, mostly from Chachro, had the index: 35S:61T:4G::77(6):23(7)—similar to that of the May incursion on the Mekran reks.

Similarly individuals were found at Barmer, in the Mallani area, and at Sorah and Akro in the Khairpur State by the middle of June.

In the *northern areas*, the first locust of the season was noted at Nokh on 31 May, after which 11 locusts were found between 11 and 20 June. None was noticed after this date in the Nokh area. On 16 June, a male locust with 8 eye-stripes and yellow wings with mauve base was collected between Phulia and Gurha in South Jaisalmer. In Sardarshahr, the first locust was found on 21 June, and none later on. In south Bikaner, two locusts were noted at Surpura on the 9th. An examination of 13 specimens of this period in the northern desert indicated the facies: 64S:27T:9G::70(6):30(7-8).

The origin of the May incursion. The sudden increase of population noticed on all the rek areas of Mekran and Lasbela after 26 May, and the appearance of locusts of a recently developed brood at Chachro, Barmer, Nokh and Sardarshahr, and in the Khairpur, Mallani and Jaisalmer areas during May-June are fairly convincing evidence of an incursion, on a small scale, of individuals from an external source. Part of the population was probably derived from the light breeding that had occurred in Kulanch and Kolwa in April-May, resulting in a population consisting pre-dominantly of 6-striped forms. Outside British Mekran, good winter rainfall is known to have occurred only at Muscat and at Charbar, the precipitation at Jask and Sharjah being low. While no inferences can be made in the present state of our knowledge as to the occurrence of breeding in the Muscat area, it is fairly certain that a fair amount of breeding had taken place in the Charbar coastal areas, and possibly also in the interior of Iranian Mekran. Owing to a lack of rainfall in April-May, there was apparently, only a single generation, which finished its eastward migration early during May-June, unlike the previous year when it continued into July-August.

The following meteorological data extracted from the Monthly Weather Data of the India Meteorological Department for 1936 show the conditions under which migration had taken place.

Monthly Meteorological Data for April-June, 1936, for the Western Areas.

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain
	Mean Max.	Highest Maximum	Date	8 A.M.	5 P.M.	8 A.M.	5 P.M.		
	In degrees F.			Percent					(Inches)
April 1936.									
Seistan (Iran)	86·6	98	30-iv	72	40	Cm; NW	Cm; NW	1·1	Nil
Nokkundi	92·5	106	30-iv	37	26	NE; N; Cm	NW; SW; W	2·6	0·04
Dalbandin	89·4	101	29, 30-iv	39	23	Cm; NE	SW; S; W	2·8	Nil
Panjgur	90·6	101	29, 30-iv	29	14	NE; E; N	SW; NW; N	1·7	Nil
Pasni	90·8	98	21, 22-iv	62	61	W; NW	SW; W	1·5	Nil
Jask	..	..	..	67	60	W; NW; NE	SW; NW; SE	1·2	Nil
Sharjah (Oman)	86·5	99	28-iv	59	58	S; Cm	W; NW	2·3	0·11
Sibi	98·8	112	30-iv	18	..	Cm; NW	..	1·1	Nil
May 1936.									
Seistan (Iran)	98·8	109	29-v	70	48	NW; N	NW; Cm	1·2	Nil
Nokkundi	107·6	115	30, 31-v	42	27	N; SE; NE	N; NW; E	1·6	Nil
Dalbandin	104·5	113	31-v	37	24	Cm; E	SE; S; SW	0·8	Nil
Panjgur	103·2	109	28, 31-v	39	15	NE; N; E	NW; N; SW	1·1	0·58
Pasni	94·0	107	6-v	72	60	W; E	SW; W; S	2·7	Nil
Jask (Iran)	..	..	..	63	59	NE; W; E	W; SW; S	1·5	Nil
Sharjah (Oman)	95·1	108	22-v	49	56	S; SW; Cm	W; NW; SW	1·2	Nil
Sibi	113·7	118	14-v	22	..	Cm	..	0·5	Nil
June 1936.									
Seistan (Iran)	103·5	112	6-vi	50	29	NW; Cm	Cm; NW	0·8	Nil
Nokkundi	109·7	116	18-vi	47	..	N; E; NW	N; NW	0·4	Nil
Dalbandin	108·5	113	4, 6, 19-vi	39	29	Cm; W; SW	NW; SW	0·3	Nil
Panjgur	104·9	112	17-vi	46	22	SW; W; NW	N; NW	1·0	Nil
Pasni	93·2	104	24-vi	72	66	W; E	SW; W; S	4·4	Nil
Jask	95·5	100	16-vi	67	60	NE; E; NW	SW; S; W	0·5	Nil
Sharjah (Oman)	94·2	103	25-vi	68	61	S; SE	NW; W	1·3	Nil
Sibi	110·8	118	19-vi	43	..	Cm; S; SW	..	0·3	0·07

It may be noticed from the above data that climatic conditions were not excessive during April in the interior of Baluchistan, whereas during May and June high temperatures and low humidity prevailed there, especially in the afternoons. Data from the Indian Daily Weather Reports for May 1936 indicated that, since the second week of May, temperature maxima as high as 109 to 115°F. as well as low humidity percentages were recorded, and during June these conditions continued to prevail till the 23rd, after which they were considerably modified by a temporary extension of the influence of the monsoon in this area. The prevalence of northerly winds at the close of May would appear to have directed the flight of the solitaries from the interior of Mekran to the coastal areas,

and thus brought about the incursion noticed on the Pasni reks at the end of May. On the other hand, so long as the normal south-west winds prevailed, the migration of locusts was probably directed towards Upper Sind and Rajputana.

Summer breeding. As already mentioned, migrant locusts, with pinkish or mauve wing-bases, were found in small numbers all over the desert areas. After rainfall, by the last week of June, the mauve tinge was replaced by bright yellow indicative of sex maturity. Egg-laying occurred in all areas of good rainfall. As rainfall was generally heavy and fairly well-distributed, fairly dense breeding occurred in many places. Hoppers were first noticed in the latter half of July and were observable till the first week of November. Since the extent and intensity of breeding was found to be closely dependent on the character of the rainfall, the breeding observed during the monsoon season will be dealt with under the appropriate period of rainfall.

1. *The first batch of breeding.* Though the monsoon commenced rather early, the first showers of the monsoon were received in the form of thunderstorm rain between 20 and 26 June in Western Rajputana. At the end of June a depression which passed across the desert gave general rainfall over the whole area between 29 June and 4 July. But the areas of good rainfall were rather restricted, the zone of good falls being confined to a long strip, 30 to 40 miles broad, passing along the line—Mahajan, Bikaner, Sri Kolayatji and Jodhpur, with the result that both Nokh and Sardarshahr, lying on either side of this strip did not receive any rain. Good rainfall was recorded during the passage of this depression, also in the Thar-Mallani area and in south Jaisalmer.

The northern desert areas. Owing to lack of rainfall, neither adult locusts nor hoppers were met with at Nokh during the greater part of July. On the other hand, both adults and hoppers were found at Girasar about 25 miles to the north-east, where rain had fallen. On 28 July several hoppers were found between Nokh and Girasar on ground thickly carpeted with young lush growth of *'Bekkar'—Indigofera cordifolia.* They were also met with in similar situations between Girasar and Sri Kolayatji. Some of them were of the IV and V instars, but the majority were much younger and several were first stage ones. The older hoppers evidently belonged to the earliest batch of eggs, laid probably soon after the showers of 20 to 25 June. It was rather remarkable that a collection of IV and V instar hoppers of this batch produced, when bred in a cage, individuals with 8 eye-stripes, and during a subsequent visit to this part of the country, *viz.* between Girasar and Bikaner and thence up to Mahajan, several 8-striped locusts were collected from nature in September. The younger batches of hoppers are presumably referable to oviposition after rainfall at the end of June. The first adult of the new generation was collected on 19 August in the east Jaisalmer area. There was no breeding in the Sardarshahr area.

The southern desert areas. At Chachro, hoppers could be located only on 3 August, but as they were of the II instar already, they must evidently have hatched during the latter part of July. Moreover, a freshly emerged adult was collected on the 10th August at Chachro, and in the southern Thar area, a new brood adult was noticed at Hayat-jo-Tar as early as 3 August, so that obviously the first eggs must have been laid in these areas soon after thunder-shower rain of 22 june. In the Barmer area, the first adult was noticed on 17 August between Sheo and Barmer.

Hoppers of various stages were met with in the Chachro area till the end of August, and with two exceptions, none was found during September. Since I-instar hoppers were noticed as late as 21 August, egg-laying had apparently been continuing 5 to 6 weeks after the last heavy fall (3·87 in.) on July.

Biometrical index in July

Northern desert areas: 46 specimens: 65S:33T:2G: :78(6):22(7).

Southern desert areas: 37 specimens: 75S:11T:14G: :81(6):19(7).

The general characters of the population found in the desert area in July are thus more or less of the type of the May incursion on the Mekran reks.

2. *The second batch of breeding.* There was little rainfall in the desert during the greater part of July and the drought continued in the greater part of Rajputana till the second week of August, when a depression passing from Central India north-west-wards across north Rajputana towards Bahawalpur caused very heavy rainfall in parts of Bikaner and Jaisalmer, between 12 and 16 August. Among the localities affected by the burst of rain in August were Ratangarh, Sri Dungargarh, Surpura, Sri Kolayatji, Gajner, Girasar, Nokh, Bap, Phalodi and Lathi. The amount of rainfall varied from 5 to 15 inches at these places, most of which was received in the course of a week. Subsequently there was further rainfall, between 19 and 22 August, which affected parts of the southern desert also. However, there was not much rainfall in the southern areas, so that the second batch of breeding was restricted mostly to the northern parts.

No locusts were met with at both Nokh and Sardarshahr outposts during the greater part of July and the first ten days of August. They began to appear there only after the occurrence of heavy rainfall.. The locusts that were first noticed were mostly mature individuals with bright yellow wings, which apparently laid eggs almost immediately. There is little doubt that the appearance of locusts at Nokh and Sardarshahr in good numbers is to be attributed to the agency of winds accompanying the passage of the depression across the desert. As the storm track was oriented south-east to north-west, strong south-westerly, southerly or south-easterly currents, that should have formed part of the cyclonic circulation in the course of the advance of the depression, had probably carried the locusts from the surrounding areas of the desert into the centres of rainfall.

As mentioned already, adults of the new generation had begun to appear by the middle of August in the southern areas of the desert and also in the Bikaner area, and in the latter half of the month, individuals of the new brood were also found in the areas of heavy rainfall. Field observations clearly indicated that some of the females of the new generation had reached sex-maturity by the end of the August and the beginning of September and had even laid eggs already, as was evidenced by sand-grains found sticking to the ovipositors of some of the females. Hoppers began to emerge early in September and were seen till the third week of October. While the earlier hatchings should have been connected with the old brood, the later batches were evidently the progeny of the mature adults of the new one. These deductions are supported by cage observations made at Sardarshahr, in which hoppers collected from the Girasar

area had been kept for rearing. They moulted into adults by the middle of August, and eggs laid by one of the females were found to hatch on 19 September, which clearly proved that such hoppers represented a second generation.

Quite large numbers of hoppers were observed wherever heavy rainfall had occurred, especially in the Bikaner, east Jaisalmer and Bahawalpur desert areas. (Pl. 16). Gregarious hoppers, however, were not encountered anywhere.

Biometrical index of the Population in August. Locusts found in the desert areas in August consisted partly of the old brood and partly of the adults of the new one, which began to appear on the scene from about the second week. An examination of the new *generation* individuals collected in the Thar-Mallani and Nokh areas during August gave the following index: 85 specimens examined: 86S: 13T: 1G: :82(6): 18(7). This would indicate that the new generation had a preponderance of *solitaria* ratios and of six-striped forms.

During a visit to the Dera Ghazi Khan area in September, small numbers of hoppers and locusts were met with. In the Bahawalpur-Jaisalmer desert areas in September-October, good numbers of hoppers and adults were found, including a form with 8 eye-stripes collected at Mithra on 22 September.

The following facies marked the total collections made in August in the northern and southern areas :—

Northern areas: 179 specimens: 76S:22T:2G::78(6):22(7).
Southern areas: 144 specimens: 87S:12T:1G::87(6):13(7).

3. *The third batch of breeding.*

Under the influence of a depression passing north-west-wards from Central India across South Rajputana, fairly widespread rainfall occurred in the southern parts of Rajputana and Sind, as well as in south-west Punjab and eastern Baluchistan, between 8 and 13 September. During this period, the following falls were recorded: Jodhpur 1·60 in., Barmer 1·50 in., Chachro 1·25 in., Chhor 2 in., Bahawalpore 1·50 in. and Khanpur 1 in. Light rainfall would appear to have occurred also in Bikaner and Jaisalmer areas about this period.

As a result of this rainfall, light breeding was set on foot in the southern areas. As the locust population of this period consisted almost entirely of the new monsoon brood, the hoppers that hatched out early in October from eggs laid by them, definitely represented the second generation of the monsoon. Hoppers were met with throughout October and some even in November.

In the northern areas, the light showers received in September would appear to have led to an extension of the breeding period. Quite large numbers of hoppers were noticeable in the area throughout October and a few even in November.

IV. Autumn period, 1936

(a) *Sind-Rajputana area.* In the course of intensive surveys at the Locust Outposts at Nokh, Sardarshahr and Chachro, well-marked fluctua-

tions in the density of population were noted during the monsoon months, which are tabulated below for purposes of comparison:

Average Density of Population per Square Mile per Month at the Outposts

Outposts	June	July	August	Sept.	Oct.	Nov.
Chachro . . .	91	35	651	906	23	3
Nokh . . .	53	6	294	86	664	837
Sardarshahr .	5	2	91	23	26	108

While the comparatively high population noticeable in June is due to the entry of migrants from the west, the diminution in July would appear to be due to an emigration of locusts elsewhere owing to drought during the later part of the month. The increase of population in August at Chachro was caused by the appearance of adults of the new generation, while at Nokh and Sardarshahr, it was due to the immigration of locusts from outside with the fall of heavy rains.

In September, there was a further rise in density at Chachro as a result of hoppers transforming into adults, but after 24 September very few locusts were found in the course of surveys, as almost the whole population emigrated from the area after the occurrence of a dust-storm on the 25th. The locusts found in October and November represented adults of the second generation transformed from the hoppers found in October. Similarly there appears to have been an emigration of adult population at Nokh and Sardarshahr during September, but as large numbers of hoppers were present in the desert, a considerable rise in the population occurred in October and November, as they gradually transformed into adults.

Causes of migration in autumn. Although as a result of general studies of the climatic conditions prevalent in the desert, it was known that the autumn migration was due to the changes in the weather conditions that set in with the withdrawal of the monsoon about the middle of September, no information was available as to how exactly the migration was caused. The problem was studied by Bhatia at Chachro during the autumn of 1936 and the detailed figures collected by him in this connection are tabulated below. The data relate to the transitional period—1 September to 31 October, which has been divided into sub-periods of six days each averages being worked out for each sub-period, the elements selected for comparison being maximum temperature, minimum humidity, evaporation, rain, clouds. wind-direction and storms. (*Vide Graph* 14).

Living as it does on the surface of sandy soils the locust is very sensitive to changes in the conditions affecting the soil surface, especially if they should have a tendency to affect the moisture content of its body. Conditions of high saturation deficiency are obviously adverse to its well-being, and usually cause it to abandon such uncongenial environment The data tabulated below indicate that from about 19 September there was a general rise in the temperature maxima of the atmosphere as well as of the soil surface as affected by direct solar radiation, and a considerable drop in the relative humidity of the air, resulting ultimately in an increase in the general evaporative power of the atmosphere. These changes were obviously due to the withdrawal of the monsoon, for with the disappearance of clouds and of moisture laden air currents, the sandy soil would, by becoming heated by the sun's rays, be rapidly divested of all moisture. Such conditions would, therefore, be very uncongenial to the life of the locust and would presumably have the effect of causing it to leave the area by taking flight. Of course, it cannot be supposed to

have any idea as to where it would be reaching, for its movements when once it has risen into the air, will be governed mostly by the direction of the air-currents, but more often than not, the seasonal winds will transport it to areas where rainfall is likely.

Metreorological Data Recorded at Chachro Outpost between 1 September and 31 October

Month and Date	Open Black Bulb—2" above ground Avg. Max. Temp. Degree Centigrade	Screen			Wind Direction		Cloud	Rainfall	General Remarks on weather during period	Average Locust Population
		Ave. Max. Temp. Centigrade Degrees	Avg. Min. Relative Humidity per cent	Evaporation C. C.	Forenoon	After noon				
September 1936.										
1—6th	49·9	35·8	49	10·90	SW	SW	Cloudy	Nil	..	1234 p.s.m
7—12th	47·9	34·8	55	8·03	Cm. SW; NB.	N;SW	Cloudy	1·25 recorded on 10—ix	Dust storm on 7th from E. on 8th from N. on 9th from N.E.	864 p.s.m
13—18th	49·3	3·39	46	13·63	SW	SW	Cloudy	Drizzle	Mostly cloudy	1173 p.s.m
19—24th	51·2	36·2	39	14·15	N;SW	Cm S., SW	Light clouds	Nil	High Temp.	680 p.s.m.
25—30th	55·1	41·3	26	19·65	N; NW; NE	S; W; NW	Partly cloudy	Drizzle	High Temp. Dust storm on 25th 7 P.M. from NE.	120 p.s.m
October 1936.										
2—6th	53·2	40·3	28	16·28	NE; S; SW	W; SW	Light clouds	Nil	Cloudy at times	94 p.s.m.
7—12th	49·8	37·1	36	15·40	S;SW	E;SW	Do.	Nil	Dust storm on 7th	Nil
13—18th	51·7	37·1	25	14·28	Cm;E; SW	SE; SW	Do.	Nil	Cloudy at times	Nil
19—24th	51·2	37·7	25	13·70	E; S; SW;NW	W;SW	Nil	Nil	Bright Sun Fog on 22nd.	32 p.s.m.
25—31st	50·1	37·4	19	16·80	N;NE; SW	N; NE NW	Nil	Nil	Sunshine, Fog on 27th. Moderate breeze in afternoon.	27 p.s.m.

The tabulated data also show that fairly good numbers of locusts were being met with at Chachro till 24 September and that, after the dust-storm which occurred in the afternoon of the 25th, very few locusts were seen in this area, the small number found at the end of the month representing the new generation derived from the September oviposition.

The conditions analysed above would appear to have been fairly typical of the situation in most of the desert areas at this time of the year, though the actual degree of development of the different factors at particular places would depend on local conditions of rainfall and vegetation. The following notes on meteoroligical data extracted from the Monthly Review of the India Meteorological Department for 1936 give a general idea of the climatic changes that occurred in the Rajputana area between August and December.

Monthly Meteorological Data for the Period, August to December, 1936, in Western Rajputana

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud	Rain
	Mean Max. (In Degrees F.)	Highest maximum (In Degrees F.)	Date	8 A.M.	5 P.M.	8 A.M.	5 P.M.		
				Per	cent.			Amount	(In-ches)
August 1936.									
Bikaner . .	94·8	104	4-viii	71	46	SW; S; W	S; SW; W	4·4	13·27
Jodhpur .	94·2	102	5-viii	72	44	SW; W; S	SW; S; W	7·5	2·38
Barmer	94·8	101	19-viii	76	50	SW; W; S	SW; S; W	6·9	1·30
September 1936.									
Bikaner . .	96·7	103	26, 28-ix	62	37	SW; SE; Cm	SW; S; Cm.	1·1	0·61
Jodhpur . .	96·1	103	4 days	67	40	SW; Cm; NE	S; SW; NE	2·9	1·65
Barmer . .	96·7	104	5 days	67	41	SW; S; NW	SW; W; E; SE	3·3	1·56
October 1936.									
Bikaner . .	96·9	102	6-x	28	18	SW; SE; S	W; SW; N	0·2	Nil
Jodhpur . .	99·5	105	6, 7-x	38	16	Cm; SW; NE	Cm; NE; SW; NW	0·2	Nil
Barmer . .	99·1	104	4, 5, 6-x	52	34	W; NW; SW	SW; W; E	0·8	Nil
November 1936.									
Bikaner . .	84·0	94	2-xi	46	24	SE; E; NE; S	W; NW; NE	1·3	0·58
Jodhpur . .	87·5	96	1, 2-xi	49	29	NE; N	NE; Cm; N	2·7	1·53
Barmer . .	87·6	96	2-xi	56	39	NW; N; E	NW; NE; N	3·1	0·29
December 1936.									
Bikaner . .	74·2	88	1, 2-xii	64	30	Cm; SE; E	Cm; W; NW N	3·6	Nil
Jodhpur . .	78·3	88	1, 2-xii	53	26	NE; N; Cm	Cm; NE; N	1·6	Nil
Barmer . .	78·7	89	2-xii	59	37	NW; N; W	E; NE; NW	2·1	Nil

It may be noticed from the above data that climate conditions were moderate all over the Rajputana area in August (except for a few days in the first week) and that with the withdrawal of the monsoon by the middle of September conditions of high temperature and low humidity prevailed, specially in the latter part of September and the first fortnight of October. By beginning of November, however, temperatures had considerably fallen, and the humidity had also risen to a certain extent, and during December these conditions became intensified.

At Nokh and Sardarshahr, the fairly high locust population that was present during August began to disappear during the latter part of September and the first week of October, evidently by migration by reason of the unfavourable weather conditions then prevailing. During the later half of October and in November, a very considerable rise in numbers was noticed, as a result of the large hopper population changing into adults. Owing, however, to the general fall of temperature and the rise of humidity with the advent of the cold weather, the locusts apparently

did not feel any great urge for migrating out of the area, and most of them would appear to have passed the winter in these areas, seeking shelter at the base of bushes at night.

Biometrical Index of the population in autumn. The following are the results of an analysis of locust collections made in September, October and November in the desert areas.

September 1936.—*Northern areas*: 35 specimens: 81S: 19T: 0G: :38(6): 62(7).

[As some of the specimens collected in September had 8 stripes, the proportions should have been shown as 38(6):50(7):12(8), but as 8-striped individuals are in reality only extreme forms of the 7-striped ones, they have been grouped together for the sake of uniformity.]

Southern areas—(*Thar-Mallani*): 90 specimens: 84S: 16T:0G: :56(6): 44(7).

October 1936.—*Northern areas*: 250 specimens: 70S:29T:1G: :46(6): 54(7).

Southern areas.—(*Thar-Mallani*): 21 specimens: 85S: 15T:0G: :47(6): 53(7).

November 1936.—*Northern areas*: 149 specimens: 75S:25T:0G: :51(6): 49(7).

Southern areas.—(*Thar-Mallani*):4 specimens: 75:25T:0G: :25(6): 75(7).

The population found in September in both the northern and the southern areas was mostly composed of the first generation of the monsoon mixed with a few remnants of the old brood, but most of this had emigrated by the beginning of October. The locusts noticed during October, November and December were mostly the second monsoon generation. While in the first brood there was a preponderance of 6-striped forms, in the second, 7-striped forms were relatively in large numbers. At Sardarshahr, one specimen with green algae was found in November, and another also with algae in December.

(b) *Lasbela area.* During the first three weeks of September, the locust population was very thin, being only 50 to 80 per square mile, but in the last week of the month, especially on the 28th and the 30th, a sudden rise in numbers was observed, the average for that week working out at about 236. While the locust individuals met with during the first three weeks were mostly locally bred ones with hyaline or light yellow wings, the bulk of the individuals collected on the 28th and the 30th consisted of forms with conspicuous mauve colour at the base of the wings.

Though there is no direct evidence as to a transfer of locust individuals from one part of the country to another, the fact that the disappearance of almost the entire population in the Chachro area after the occurrence of a dust-storm on 25 September was followed about three days later by a sudden rise in the numbers of locusts in the Lasbela area, is rather strongly suggestive of such a transference.

Several such rises in the density of population at intervals of ten to fifteen days were noted on the Ambagh reks during October, November, and December, for instance, between 6 and 12 October, again between 28 October and 6 November, and again on 12 November. The density on such days often exceeded 1,000 per square mile and the average population figure for September, October and November were 137. 449 and 659

respectively. Most of the locusts found at the time of such increases had hyaline or light yellow wings, with pink or mauve wing-bases, indicating their migrant character. Very often they carried red mites, which showed that they had come from an area of good rainfall. Moreover, four specimens of eight-striped forms of the locust were collected on the Ambagh reks, one on 28 October, a second on 3 November, a third on 8 January, 1937, and a fourth on 29 January, and since the Bikaner area was the only region where forms with 8 eye-stripes had been found in nature, it is surmised that they had been derived from that area.

Breeding. A few stray hoppers were noticed in the Naka-Kharrari, Kathor and Goth-Sherkhan areas during October, and some elsewhere. There is thus little doubt that the considerable rises in population noted in September, October and November were mostly caused by the entry of migrants from outside.

Biometrical index of the population. Collections of locusts pertaining to the autumn period showed the following indices:

September, 1936: (26 specimens): 65S:31T:4G: :50(6):50(7).

October, 1936: (91 specimens): 67S:30T:3G: :43(6):57(7).

November, 1936: (51 specimens): 67S:31T:2G: : 45(6):55(7).

The characters of the populations are, on the whole, homogeneous and show definite relationship to the type produced in the desert.

Hinidan and Hingol areas. During a tour in the Hinidan area, small numbers of locusts—presumably locally bred ones, were found at Goth Sherkhan in September. In the Hingol area locusts with bluish or mauve wing-bases were met with in October in fair numbers in many places, and in much larger numbers in November.

(c) *Mekran area.*—1. *Mekran interior.* No locusts were observed during the autumn months in the interior valleys with a few exceptions. At Shabaz-Kalat in Kolwa, a yellow-winged female was noticed in a cultivated field on the 5th September, and on the 13th September, another female with hyaline wings at Chamber-Kalat also in Kolwa. As dust-storms were prevalent at the time, they might possibly have been conveyed there by their agency. In October, no locusts were found anywhere, and in November, the only specimen observed was found at Goshanak in Kolwa on the 18th. It was a *solitaria* male with light yellow wings and pinkish wing-base, and six eye-stripes.

2. *Mekran coastal reks.* No locusts were met with in the Kulanch-Dasht area during the autumn months, and the only places where they were seen were the coastal reks. Even here they were in very small numbers during September. During October and November, an increase was noticed in the Pasni and Ormara reks. The following were the average figures of density per sq. mile for these months on the Gwadar, Pasni and Ormara rek areas.

Areas	September	October	November
Ormara	9	56	320
Pasni	26	63	167
Gwadar	51	26	5

The increase in October and November was due to an immigration from the eastern areas, and as the movement was from east to west, Ormara and Pasni reks had, by reason of their geographical position, a greater increment than the Gwadar area.

In September, small numbers of locusts, mostly with pink or mauve wing bases, were found on the Pasni, Gwadar and Ormara reks. At Pasni especially, the appearance of migrants was recorded between 19 and 26 September, which might be correlated with dust-storms known to have occurred on the 16th and 17th in Kolwa, Lasbela and other parts of Baluchistan. As the general direction of the storms was north-easterly, the individuals found at Pasni at this period were presumably some of the earliest arrivals from the east. The facies of the September collection (16 specimens mostly from Pasni), was 50S:50T:0G: :38(6):62(7).

In October, a similar light incursion of locusts of a recent brood was detected at Pasni early in the month, and possibly, this was part of a contingent that had reached Ambagh at the end of September. At the close of October, Dr. Roonwal noted at Pasni a fairly well-marked influx of clear-winged forms, which attracted the attention of even the local inhabitants of the Pasni Niabat. Most of them had mauve wing-bases and carried red mites. As this incursion extended even into the middle of November, it was possibly organically connected with the one noticed between 28 October and 6 November at Ambagh. A similar immigration was noted in the Ormara area in October and November, and also in the Gwadar area but only in November.

The biometrical index of the population in October and November was as follows:

October 1936: (63 specimens): 59S:41T:0G: :68(6):32(7).

November 1936: (95 specimens): 62S:37T:1G: :60(6):40(7).

The main feature would appear to be the almost complete absence of *gregaria* components.

Summary of data for 1936

At the beginning of the year, a fairly large locust population composed of (1) the surviving individuals of the 'incursion' of July 1935 and (2) the autumn migrants from Rajputana desert, was present on the Lasbela and Mekran reks, and in the Kulanch-Dasht and Kech areas.

A fair amount of rainfall was received in the Mekran areas during January, February and March but the individual falls were, on the whole, scanty and the total rainfall much below the average. The breeding was consequently light in most places. Fairly good numbers of hoppers were noticed in Kulanch, and in Kolwa an instance of incipient swarming was observed, wherein black hoppers had developed in March-April as a result of the concentration of over-wintered locusts from the coastal areas. A second spring generation was represented in Mekran solely by a few green hoppers found in a field near Thana Dargah in the Panjgur, area at the end of June.

During the last week of May, a light incursion of locust individuals with pinkish or mauve wings, probably produced partly in the interior of Mekran and partly in Iranian territory was noticed on the Mekran reks, on the Lasbela area and in parts of the Rajputana desert. The entry of migrants continued into June.

STATEMENT VI—*Results of Locust Surveys—1936*

(The figures represent the average population per square mile for the whole month in the areas surveyed and 'H' indicates occurrence of breeding)

Seasons	Months	BALUCHISTAN										SIND-RAJPUTANA DESERT							
		MEKRAN						LASBELA											
		Gwadar Pishukan	Pasni Reks. (Int. Surveys)	Ormara	Kech	Panjgur	Kulanch Dasht	Kolwa	Hingol	Ambagh Reks (Int. Surveys)	Hinidan Bela	W. Sind & Kachhi	S.W. Punjab & Bahawalpur	Chachro (Int. Surveys)	Thar, Mallani	E. Jaisalmer-W. Bikaner	Nokh (Int. Serv ys)	E. Bikaner	Sardar Shahr (Int. Surveys)
Winter	Dec. 1935	284	112	318	16	...	384	...	167	25	1	...	7	79	5	3	Nil	...	13
	Jan. 1936	603	133	714	N	...	142	...	...	100	...	...	...	49	51	Nil	4	...	Nil
	Feb. 1936	302	108	525	14	...	12	...	122	18	...	...	...	5	Nil	72	14	...	11
Spring	March 1936	161	H 58	H 196	10	22	H 119	H69	...	98	...	...	...	66	3	1	4	Nil	Nil
	April 1936	H 76	H 9	H 58	Nil	Nil	H 120	H...	H 24	19	Nil	...	...	14	Nil	H 3	Nil	...	Nil
	May 1936	H 48	H 106	H 340	25	...	H 96	...	...	94	...	...	H 34	20	Nil	Nil	4	...	Nil
Summer	June 1936	148	252	364	Nil	H 9	13	32	90	253	...	...	15	91	7	2	53	...	5
	July 1936	97	88	51	Nil	H 2	Nil	Nil	...	63	40	7	7	35	89	H 74	6	31	2
	Aug. 1936	66	48	31	Nil	Nil	Nil	18	8	H 32	...	...	...	H651	H 68	H122	H294	Nil	91
Autumn	Sept. 1936	51	26	7	Nil	Nil	Nil	2	...	137	20	Nil	H60	H906	186	H	H 86	Nil	H 23
	Oct. 1936	26	63	56	Nil	Nil	Nil	Nil	48	H 499	...	...	Nil	H2	H23	H 323	664	105	H 26
	Nov. 1936	35	167	320	Nil	Nil	Nil	4	173	659	23	...	...	2	7	H 544	H 337	18	108

The first showers of the monsoon were received in the third week of June, and this was followed by wide-spread rainfall at the close of June and the beginning of July, in parts of Bikaner-Jaisalmer area and in Thar-Mallani. Fairly good breeding followed. At this period, several adults with 8 eye-stripes were produced in parts of Bikaner area. Good numbers of hoppers were observed in the Thar-Mallani area in August, but breeding was somewhat restricted as the rainfall in the first week of July was followed by a fairly prolonged drought.

Further rainfall occurred in the second week of August, when heavy falls of over 10 inches were recorded at many places, in the northern areas of the desert. Large numbers of locusts were seen at Nokh and Sardarshahr after rainfall, and good breeding occurred, the hoppers being found in numbers during October and November. Some rainfall occurred during September, mainly in the southern areas, and light breeding followed.

With the withdrawal of the monsoon by 19 September, a period of high temperatures and low humidity set in on the desert areas, and led to the emigration of almost the whole of the adult locust population in the southern areas and also to a great extent in the northern tracts.

By the middle of October, the temperature conditions became moderate, and the locusts of the second generation produced in the desert in October and November did not apparently feel the urge for migration and passed the winter there.

During the autumn months, a distinct rise in the locust population in the Lasbela and Mekran reks was noted, and the increase was evidently due to the entry of individuals of a new brood with hyaline wings and bluish or mauve wing-bases.

Throughout the year 1936, very few individuals with *gregaria* ratios were noticed. The components of the May incursion were mostly composed of locusts with *transiens* ratios and six eye-stripes, while the locusts bred in the monsoon period in the desert had a greater proportion of *solitaria* ratos and forms with 7 eye-stripes. The appearance of forms with 8 eye-stripes may be regarded to a certain extent as the climax in the development of the *solitaria* phase.

CHAPTER VI

Year 1937

Weather notes for 1937

Winter rainfall 1936-37. The first western disturbance of the winter (period) of 1936-37 made its appearance in the last week of October, 1936, and in the winter-spring period of 1936-37 there were altogether 63 different disturbances.

In November, 1936, there was no rain in the Mekran area, but fairly good rainfall was recorded in the Persian Gulf area: Sharjah 4·5 in., Bushire 1·9 in., Jask 1·0 in., and Muscat 0·5 in. In December 1936, further rainfall occurred in the same area: Sharjah 1·4 in., Bushire 1·3 in., and Bahrein 2·3 in., though little or none on the Mekran coast. In the interior of Baluchistan, however, there were fairly good falls, as also in the Lasbela and Kachhi areas. January 1937 proved to be a dry month on the whole, except for the last week, when Muscat registered the only considerable fall of 1·14 in. Between 8 and 12 February, a disturbance developed into a deep depression over west Rajputana and gave fairly extensive rain in the Jaisalmer, Bikaner and Bahawalpur areas and also caused some rainfall in the interior of Baluchistan. Some of the principal falls were Bikaner 1·5 in., Fort Abbas 2·5 in., Nokh 2·17 in., Anupgarh 3·88 in., Bhatinda 2·25 in., Sri Kolayatji 1·85 in., and many places in the Jaisalmer State recorded falls varying from 1·50 in. to 2·68 in. A second disturbance caused extensive falls in Upper Baluchistan and the Punjab on 23 and 24 February, Quetta receiving 2·5 in., Sibi 0·5 in., Gandhawa 1·34 in., Bhag 1 in. and Jacobabad 1 in. March was dry, on the whole, the only significant fall being 0·63 in. at Sharjah. During the first week of April, a disturbance was active in Sind, Baluchistan and Punjab giving considerable rain in the interior: Dera Ismail Khan 2 in., Multan 0·80 in Jacobabad 0·70 in. and Pasni received the only good shower of the season —0·62 in. The month of May was mostly dry.

Monthly rainfall data for winter-spring season, 1936-37

Localities	Nov. 36	Dec. 36	Jan. 37	Feb. 37	March 37	Apl. 37	May 37
Iran							
Jask	1·15	..	0·25	1·31	0·10	..	..
Charbar	0·52	..	0·21	0·39	0·08	..	..
East Arabia							
Muscat	0·49	..	1·14	1·77	..	..	..
Sharjah	4·44	1·44	0·04	0·98	0·63	..	..
Baluchistan							
Pasni	0·05	0·27	0·01	0·26	0·02	0·62	..
Gwadar	0·04	0·04	0·56	0·48	0·09	..	..
Ormara	..	0·89	..	..	..	..	..
Turbat	..	1·05	0·50	1·20	0·22	0·34	..
Panjgur	..	0·26	0·54	1·60	0·18	0·29	..
Gandhawa	..	1·48	..	1·34	0·90	0·98	..
Sibi	..	0·89	0·48	0·95	0·57	0·38	0·09
Quetta	..	4·44	1·47	3·54	1·46	0·46	0·41
Bela	..	3·34	..	1·46	0·70	..	..
Rajputana							
Sri Ganganagar	..	..	..	1·54	0·21	0·77	0·59
Bikaner	0·53	..	..	2·08	..	..	..
Jodhpur	1·53	..	0·79	..	..	..	..
Barmer	0·29	..	0·40	..	..	..	..
Punjab.							
Dera Ghazi Khan	..	1·48	0·04	0·98	0·49	1·42	0·05
Taunsa	..	0·76	..	0·90	0·23	0·74	0·19

It is thus seen that there was a failure of rainfall in the winter-spring season all along the Mekran coast of Iran and Baluchistan, whereas fairly good rain was received in eastern Arabia, especially at Sharjah, and in the interior of Baluchistan and in Lasbela.

Monsoon rainfall 1937. The earliest advance of the south-west Monsoon was recorded in Ceylon on 16 May, and by the end of the month the current was fully active in the Bay of Bengal. The monsoon established itself early in June in the Peninsula and North-East India, but its influence extended to North-West India only by the end of the month. Unsettled weather off the Kathiawar Coast on 24 June caused heavy rainfall in Gujarat and southern Rajputana, while a Bay depression passing across the Central Provinces and Rajputana brought an extension of rain fall into East Rajputana and Sind. During July, fairly heavy rainfall occurred in many parts of the desert under the influence of three depressions that reached the area from the Bay of Bengal. At this period, good precipitation occurred in the eastern parts of Bikaner State and in the Shekawati area of Jaipur State as also in most parts of Marwar and south Sind, whereas north-west Bikaner and the greater part of Jaisalmer received only light rainfall.

During August, the Bay depressions, which were active in North-East India, did not reach the Desert areas, so that drought prevailed in most parts of Sind, Rajputana and Gujarat. Dust-storms, however, occurred in the afternoon, on many days in the latter half of the month. In September, a low pressure area from the Far East developed on the 3rd into a depression in the Bay and travelling westward across Orissa, Central Provinces and Rajputana reached south Rajputana and Gujarat on the 9th and south Sind on the 10th. This occasioned fairly heavy rainfall in many parts of Sind, Rajputana and Gujarat. A second depression, which was active between 13 and 16 September, caused heavy falls in the Agra-Delhi-Ambala area., but did not affect the desert area except along its fringes. After 17 September, the weather was practically dry except for a few light showers at Jodhpur and Bikaner during the last week.

Monthly rainfall data for the monsoon period, 1937

Localities	May	June	July	August	September
Rajputana Area.					
Sri Ganganagar	0·59	0·18	3·38	..	0·24
Bikaner	.	..	8·86	..	0·85
Sardarshahr	0·09	0·18	4·00	0·29	2·01
Sadulpur	.	1·42	8·28	1·07	2·54
Jhunjhunu	.	1·16	11·30	0·70	2·55
Sikar	.	2·96	8·63	Not known	..
Churu	0·28	1·21	7·59	0·13	2·24
Nohar	..	0·50	8·45	0·20	0·37
Sri Kolayatji	..	..	4·20	..	1·25
Lunkaransar	..	0·90	6·60	..	1·60
Suratgarh	..	..	2·58	0·10	0·37

Monthly rainfall data—contd.

Localities	May	June	July	August	September
Anupgarh	..	0·31	0·72	..	..
Nokh	..	0·03	2·77	..	0·91
Bap	..	..	2·65	..	1·47
Jaisalmer	..	..	5·91	..	1·32
Phalodi	..	0·09	9·73	..	2·98
Jodhpur	..	0·26	5·83	..	3·97
Barmer	..	0·14	7·56	..	1·51
Mandar	..	5·68	10·99	..	10·13
Sind Area.					
Chachro	..	0·17	5·86	..	2·62
Karachi	..	..	8·65	..	0·03
Jacobabad	..	..	1·77	..	..
South Punjab.					
Hissar	..	0·65	10·10	0·81	5·30
Fort Abbas	..	0·30	4·57	..	0·32
Dera Ghazi Khan	0·05	0·08	2·85	0·02	0·32
Taunsa	0·19	..	1·56	0·20	0·20
Baluchistan area.					
Gandhawa	..	..	3·15	..	..
Bhag	..	..	1·51	..	..
Sibi	0·09	..	0·89	..	..
Bela	..	..	4·08	..	..
Ambagh	..	..	3·13	..	..
Ormara	..	..	0·75	..	..
Pasni	..	..	0·11	..	..
Panjgur	..	..	0·20	..	..
Turbat	..	..	0·03	..	..

The main feature of summer rainfall in 1937 were (1) in the Desert, heavy rain in July followed by a pronounced drought in August and light rainfall in September, (2) in Lasbela, a fair amount of rain in July followed by drought and (3) in Mekran a lack of summer rainfall.

Observations on Locust Distribution in 1937 (*vide* Statement VII)

I. Winter period 1936-37

(a) *Sind-Rajputana area.—Southern desert areas.* Except for three individuals at Chachro during the first week of December, 1936, no locusts were met with anywhere in the Thar-Mallani desert areas. The last specimen of the season was collected on 8 December at Chachro and thereafter no locusts were noticed till June 1937.

Northern desert areas. No locusts were met with in the Khairpur and South Jaisalmer areas during winter months. A fairly high population was, however, noticeable in the East Jaisalmer and West Bikaner areas where heavy breeding had taken place during September, October and November 1936. At Nokh, a fifth-stage hopper was collected as late as 2 December, 1936, and quite large numbers of locust adults were encountered during the month around Nokh. Fairly good numbers were also noted in the Pugal-Rojri area of Bikaner, the Rukanpur-Derawar area of Bahawalpur and Nokh-Barsilpur area of Jaisalmer. At Sardarshahr only four locusts were found in December.

In January 1937, the population at Nokh was much thinner, the average density for the month being about 114 per sq. mile as against 766 for December. Field observations around Nokh indicated that locusts generally retired to the base of dense bushes (Pl. 17) during the prevalence of frosty weather and crawled out into the open only at mid-day on sunny days. As specimens of dead individuals or their wings were often met with at the base of the bushes, it is evident that severe frosts had taken a toll of the locust population. In the course of tours, small concentrations were found in the Lathi-Baru area of Jaisalmer on 18 and 19 January. At Sardarshahr, only one locust individual was noticed on the 25th.

In February, fairly widespread rainfall about 2 inches on the average was received on the 11th and 12th in the Jaisalmer-Bikaner areas, and the weather was also comparatively warmer than in January. At Nokh fairly large numbers of locusts were met with up to 18 February, but thereafter few were noticed. The average density for the month was about 180 per sq. mile, (*vide* Table VII). Fairly good concentrations of locusts were noticed in the Lathi-Baru-Nokh region between the 16th and the 20th (300 to 1,000 per sq. mile). Some of the females had mature eggs and in one case (25 February) froth and sand-grains were found sticking to the ovipositor indicating that it had already laid eggs.

Towards the end of February, a perceptible decrease in number was noted at Nokh and as on locusts were seen in March after the 3rd, migration had apparently been taking place since the middle of February. Similarly, at Sardarshahar four individuals were seen in the latter half of February, but none in March. Very few locusts were found in the Bikaner area during February except at Sonpalsar and Malkisar (25-26/ii).

Biometrical index of the population.—Jaisalmer-Bikaner areas: Winter 1936-37.

December 1936: (28 specimens): 67S:29T:4G: : 32(6):68(7).

January 1937: (21 specimens): 76S:19T:5G : :57(6):43(7).

February 1937: (50 specimens): 76S:24T:0G: :42(6):58(7).

(b) *Lasbela area.* A fairly high population was noticed on the Ambagh Rek areas during December 1936, the average density being as high as 501 per sq. mile. As in the previous months many of the specimens had their lying-bases tinged with mauve or pink, indicative of migration, but with the fall of fairly heavy showers on the 8th (0·41 in.), 10th (1·05 in. and 24th (0·67 in.), most of the locusts in the Ambagh area would appear to have developed yellow colour on the wings and some were also observed pairing, though apparently egg-laying did not occur.

There being no rainfall, most of the yellow-winged individuals were found to have disappeared by mid-January, and in their stead, specimens with light yellow wings with mauve wing-bases were noticeable. A marked increase in numbers was observed on particular days indicating presumably the arrival of fresh migrants. Such rises were, for instance,

observed on 17 and 29 January. Two individuals with 8 eye-stripes were detected during January—one male on the 8th, and the other a female on the 29th. The average density for January was 115 per sq. mile.

In February, there was a further decrease of population, the density being only 94 per sq. mile. In spite of two sharp showers—0·31 in. on the 10th and 0·61 in. on the 24th—there was no indication of breeding on the Ambagh area, but in the Khandewari and Hingol areas—which were visited between 27 January and 10 February, fairly good numbers were found, of which many had bright yellow wings and some had mature ovaries. Good rainfall on the 10th and presumably led to egg-laying here, as a few hoppers were noticed in the Khandewari area early in March.

Biometrical index of the population in winter

December 1936: (34 specimens): 64S:36T:0G: :45(6):55(7).

January 1937: (39 specimens):60S:40T:0G: :50(6):50(7).

February 1937: (26 specimens): 71S:25T:4G: :35(6):65(7).

It is rather remarkable that, in the relative proportions of the phases and the eye-stripes, the February index of the Lasbela area should resemble that of December in Rajputana, while the December and January ones of Lasbela with those of October and November in north Rajputana.

A few specimens of December, 1936, and several of those of January and February, 1937 (38 per cent. and 30 per cent. respectively) from the Lasbela area were noticed to have *green algae* on the wings.

(c) *Mekran area.*—(i) *Mekran interior.* Except for a single female with hyaline wings and mauve wing-bases collected on 4 December 1936 between Gar and Rohtak, no locusts were seen in the Kech, Kolwa and Panjgur areas. In the Kulanch-Dasht area, too none was met with during December and January except for one female collected at Kuhak on 22 December 1936, but several were found at Kuhak, Shahjangi-Kalat and Nokbur about the middle of February. Nine specimens of this period showed the facies: 67S:33T:0G: :78(6):22(7). Most of them had yellowish wings and a few showed traces of mauve. Two carried a few colonies of *green algae* on the wings, and were presumably migrants from the coast.

(ii) *Mekran coastal reks.* In December, a fairly high population was noticed at Ormara and Pasni, but there was a perceptible diminution in January and February, which was evidently due to lack of rainfall along the coast. The following were the average figures of density during December, January and February on the Ormara, Pasni and Gwadar reks.

Areas	December	January	February
Ormara . . .	254	60	53
Pasni	110	27	14
Gwadar . . .	7	6	7

The decrease was presumably caused by migration westwards during December and January, and possibly from the coast into interior during

February, as indicated by the appearance of locusts in Kulanch and Kolwa during February and March.

Biometrical index of the Mekran rek population

December 1936. (81 specimens)—53S:43T:4G: :55(6):45(7).

January 1937. (39 specimens)—62S:28T:10G: :53(6):47(7).

February 1937. (24 specimens)—65S:35T:0G: :42(6):58(7).

Most of the specimens of December and January had hyaline or light yellow wings with pinkish or light mauve bases, but many of those found in February had yellow wings. Some collected in Januray and February had *green algae* on the wings.

II. Spring period, 1937

(a) *Mekran area.*—(i) *Mekran coastal reks.* There was practically no rainfall during winter on the coastal areas, nor was there any rain during spring except for half an inch on 1 April at Pasni. Consequently there was no breeding on the reks during spring, and few locusts were met with. As light increase of poulation was, however, noticed in May, which, in the absence of local breeding, was evidently due to immigration, as seen in the following table of population density.

Areas	March	April	May
Ormara	Nil	5	12
Pasni	11	5	12
Gwadar	Nil	Nil	5

Seven individuals collected in March and April indicated the facies 83S:17T:0G: :57(6):43(7). A small collection of 11 specimens in May had the index: 67S:33T:0G: :55(6):45(7).

Many found in May had light yellow wings tinged with mauve, and were a recent brood possibly derived from the interior of Mekran.

(ii) *Mekran interior.* While the coastal areas received little or no rainfall, the hinterland of Mekran as well as Upper Baluchistan in general had fairly good to moderate precipitation due to winter disturbances specially during December and February, and light rain during March and April. Good rainfall was reported in Kolwa at the end of March.

Whereas no locusts were seen in the Panjgur-Kolwa areas during February, several were met with in the latter part of March in Balgattar and Kolwa. Most of them had yellow or light yellow wings with a touch of mauve in some; four had colonies of *green algae* on their wings. Two specimens were observed in the Kech area on 10 March between Mand and Aspikan and six in the Kulanch-Dasht area in mid-March, mostly mature and with bright yellow wings, and one of them with *green algae.* As a first-stage green hopper was found on a Trath bush (*Haloxylon salicornicum*) on the bed of a water-course near Chambar-Kalat on 30 March, light oviposition had presumably taken place. The facies of 16 specimens of this period was 86S: 14T: OG: :44(6): 56(7). Most of this interior population had doubtless been derived from the coastal areas and were composed of the over-wintered old generation.

During surveys in April, further specimens were met with in Kulanch, Kolwa, and Balgattar. The Survey Assistant was told by a local Baloch that some hoppers had been seen in a wheat field in mid-April at Tash-i-Daf in Balgattar. During a visit to Nag-i-Kalat in the Rakhshan valley,

a female locust with light yellow wings evidently a recently developed locust was collected on 30 April near Nagin-Dap, and subsequently on 4 and 6 May in the same area four more new forms. Evidently light breeding had probably taken place in the Rakhshan valley in March-April following good rainfall.

In the Gar-Seh-Gazan area, visited between 9 and 15 May, a few locusts with yellow wings were noticed. In the Kolwa area, examined between 23 and 28 May, fairly large numbers were found, especially at Bani near Goshanak, where 26 individuals were seen on 25 May. Most of them had light yellow wings, but the colour was deep yellow in some and in one instance colonies of *green algae* were also noticeable. In a few instances the wings were hyaline, which would indicate that local breeding had occurred. Since Kolwa had received good rainfall in February and March, light breeding had probably taken place there during April-May. The average density of the Kolwa area during this period was found to be 224 per sq. mile.

In the Kulanch Dasht area, four hoppers (II & III instar) were found on 19 May on 'Kapocham' (*Chrozophora*) plants near Kuntdar in the Dasht valley, and forty-four hoppers of all stages on the 22nd, also on 'Kapocham' as well as a single adult at Nokbur in Kulanch. In the Buleda area, two yellow-winged locusts were located on 13 May between Aspikan and Mianaz.

The biometrical index of 35 specimens from Mekran interior in April-May was: 78S:19T:3G: :68(6):32(7).

Spring breeding would thus appear to have occurred in the Kulanch-Dasht, Kolwa and Panjgur areas in the interior of Mekran, whereas it was entirely lacking along the coast due to want of rainfall. Presumably the locusts population known to be present earlier in the year on the coastal tracts had emigrated thence on account of drought into the interior in February-March, and laid eggs in localities where rain had fallen.

(b) *Lasbela area.* There was a further decrease of population during March on the Ambagh reks. Only 12 individuals were met with and the average density was 15 per sq. mile. In the Hingol area, fairly good numbers were noticed, the density being found to be as high as 161 per sq. mile, but mostly in the Khandewari reks, where good rain had fallen, few being found in the western areas (Kund, Sangal and Hingol). Most of them were mature and had yellow wings, and four green hoppers of the I, II and III instar were found in this area on 6 and 18 March on bushes. In April no locusts were met with either on the Ambagh reks, or in the Hinidan area, but towards the end of the month, hoppers and fresh adults were discovered in the Sheh Lakhra area. In May, no locusts were noticed during the first fortnight around Ambagh, but during the second, small numbers were met with, many of which had bluish or mauve wing-bases—evidently immigrants. In this connection, an observation recorded on 22 May is of particular interest: 'A male locust located on the Guruchela rek at 5 p.m. escaped after capture and disappeared from sight flying high along with the wind in an eastern direction.' It was found that the population had greatly decreased in the Hingol area in May, the average density being only about 27 per sq. mile. In the Khandewari area, a few adults with hyaline wings were noticed presumably representing the locally developed spring generation.

The major event of the spring season of 1937 in the Lasbela area was, however, the discovery of fairly concentrated breeding in cultivated fields at Sheh Lakhra in the Porali valley, which should be considered to have formed a sort of 'outbreak centre' at that time.

The infestation at Sheh Lakhra. As very little breeding had been noted in previous years in the interior of the Lasbela State, survey work was usually restricted to the coastal areas. Information regarding the outbreak in the Sheh Lakhra area was obtained in 1937 more or less by accident. One of the officers of the Survey of India engaged in topographical surveys of the Lasbela State gave information that numbers of locusts had been near Sheh Lakhra early in April, on which a visit was arranged on 30 April, when in fields of mixed *jowar* (*Sorghum*) and *moong* (*Phaseolus*) at Goth Safarkhan on the banks of the Porali, (Pl. 40) a good number of recently developed locusts, as well as green hoppers, the latter mostly on one of the weeds—*Kanderi* (*Alhagi camelorum*) (Pl. 18) and to a less extent also on jowar and moong. The place was examined on 26 and 27 May, when nearly 500 adults locusts were observed in the course of surveys covering over five miles. The population density for the whole area was calculated to be about 1,894 per sq. mile, but as most of the locusts were confined to an area of about ten acres of cultivation the density of the concentrations was actually about 38,000 per sq. mile. Only small numbers of hoppers were reported to have been found, but possibly some of those hidden in the thick under-cover of thorny weeds had been missed. No locusts were seen elsewhere in the Porali valley except for a single specimen with mauve wingbase and a few *green algae* noted at Mangia a few miles north of Sheh Lakhra.

In June, the locality was visited again between the 12th and the 14th, when over 270 locusts were found in the same area, indicating a density of over 4,000 per sq. mile; in addition, a few hoppers were also found on Camel-thorn, *Aerua* and *Baro*. Only 28 locusts were found in this area on 25 June, the density of population being only about 1,000 per sq. mile. A few hoppers were, however, still noticeable.

It was evident that the population had been gradually decreasing during June, and in fact, the cultivators themselves reported that they had seen locusts flying out of their fields while harvesting *jowar* ear-heads. No locusts were found here during visits in August, September, October and November.

The probable origin of the infestation. With the heavy rainfall received in December and February, the river Porali was in flood more than once, and consequently a large area along its banks was brought under cultivation in February-March. The soils of the Porali basin are an alluvial clay loam, but the fields infested were mostly light sandy loams, on which there were, in places, especially along the river-side, small patches of fine wind-blown sand. During December, January and February, a fairly large locust population was present in the Hingol areas, but for want of adequate rainfall along the coast, there was little breeding except in the Khandewari area. There is presumptive evidence to indicate that much of this population had migrated into the interior and laid eggs in soft sand or in sandy loam along the river banks during February-March and that the hoppers hatching therefrom had infested the crops. Breeding would appear to have been more or less continuous from March to June, since hoppers were noticeable, in greater or smaller numbers, throughout the whole period. Since adults of the new generation were present in good numbers by the end of April, it is not unlikely that part, at least, of the hopper population found in June represented the second spring generation. No locusts were found at Ambagh after 31 March, and their appearance for the first time on 18 May, should be correlated with the occurrence of hot winds from the north on the 18th and the 19th, causing the maximum temperature to shoot up as high as 108°F. at Ambagh and 119°F. at Bela. It is obvious that the development of conditions of drought in the interior had much to do with the gradual disappearance of locusts from the Sheh Lakhra area.

Monthly Meteorological ata for April-July, 1937, for the Western Areas.

Localities	Maximum Temperature			Humidity		Dominant Wind Direction			
	Mean Max. (In Degree F)	Highest Max.	Date of occurrence	8 A.M.	5 P.M.	8 A.M.	5 P.M. Amount	Cluoud am-ount	Rain
				Per cent	Per cent				(Inches)
April, 1937									
Seistan (Iran)	88·2	92	9, 13, 28-iv	58	27	NW; Cm	Cm, NW	1·5	0·05
Nokkundi .	89·1	100	22-iv	45	30	N;NE;NW	N;NW;SE	2·5	1·96
Dalbandin .	87·2	96	4 days	54	29	Cm; NE	SW; NW; NE	1·8	0·51
Panjgur .	87·4	97	(2,27-v	47	31	NE; E; N	N; NW; SW	1·7	0·29
Pasni .	90·3	101	11-iv	66	61	NW; W; N	SW; W; S	1·1	0·02
Jask (Iran)	85·7	94	28-iv	67	58	E; NE; W; N	W; SW; S	1·1	Nil
Sharjah (Oman)	87·1	103	26-iv	53	52	S; SE; W	W; NW; N	1·0	Nil
Sibi . .	95·7	105	13-iv	24	...	N; NW; NE	...	2·5	0·38
Bela . .	100·0	109	12-iv	53	28	Cm; NW; N	S; SW; NW	1·2	Nil
May, 1937									
Seistan (Iran)	96·3	107	22-v	46	25	NW; Cm	Cm; NW	1·1	Nil
Nokkundi .	108·7	114	22, 23-v	38	28	N; NW; E	N; NW; S	1·6	Nil
Dalbandin .	101·8	111	23-v	43	26	Cm; S; NW	NW; SW; N	1·1	Nil
Panjgur .	100·1	109	22, 23-v	49	41	N; NE; W; NW	N; SW; NE	0·8	Nil
Pasni . .	93.1	105	20-v	73	71	W;NW;SW	W,SW	2.3	Nil
Jas k (Iran) .	92·8	99	20-iv	65	60	E; W	W; SW; S	0·7	Nil
Sharjah (Oman)	94·4	103	2, 10-v	50	57	S; SE	W; NW	1·7	Nil
Sibi . .	110·3	119	17-v	18	...	N; NW; E	...	1·3	0·09
Bela . .	106·8	120	20-v	69	39	Cm; SE; SW	S; SW; E; SE	0·8	Nil
June 1937									
Seistan (Iran)	101·5	111	5-vi	42	25	NW; Cm	W; NW; SW	1·3	Nil
Nokkundi	110·5	116	27-iv	29	16	N; NW; Cm	N; NW	0·2	Nil
Dalbandin .	109·1	114	28-iv	39	30	Cm; SW; N	S; Cm; SE	0·2	Nil
Panjgur .	105·6	111	6, 27-vi	42	29	N; Cm; W; NW.	N; NW; W	0·3	Nil
Pasni .	92·8	105	1, 4-vi	77	77	W; NW; E	S; W W; S	4·7	Nil
Jask (Iran) .	95·6	102	26, 27-vi	69	62	E; W; SE	W; SE; S	0·2	Nil
Sharjah (Oman)	95·8	105	27-vi	63	62	S; SW	W; NW	1·5	Nil
Sibi .	115·4	125	7-vi	51	...	S; SW; SE	...	0·5	Nil
Bela . .	107·2	119	1, 2-vi	65	45	Cm; S	S; SW; SE	2·4	Nil
July 1937									
Seistan (Iran)	105·7	111	20-vi	45	72	NW; N	NW; Cm	2·0	Nil
Nokkundi .	110·9	117	6-vii	29	19	N; NW; NE	N; NW	0·8	Nil
Dalbandin .	109·0	114	6-vii	51	39	Cm; W; SW	SW; W; Cm	0·9	Nil
Panjgur .	105·1	110	15-vii	64	35	SW; W; S	NW; N; SW	2·6	0·020
Pesni . .	09·1	105	3-vii	80	76	W; NW; SW	SW; W; S	7·5	0·11
Jask (Iran) .	94·0	96	6-8-vii	71	68	E; NE;	SE; S	2·0	Nil
Sharjah (Oman)	101·3	112	16-vii	62	60	SE; S; E	NW; N; W	2·3	Nil
Sibi . .	107·5	115	1-vii	52	...	S; SW; SW	...	1·8	0·89
Bela . .	100·2	107	15-vii	32	60	Cm; S.	S; SW; E	7·1	4·08

From the data tabulated above, it is seen that conditions of high temperature and compratively low humidity began to prevail from about the middle of May in the interior of Mekran and Lasbela and were presumably instrumental in causing the emigration of locusts from these areas.

Biometrical index of the population in spring. 32 specimens collected in March from Ambagh and Hingol areas had the facies: 64S:32T:4G: 59(6):41(7), (Algae found on 20 per cent. of the collections). 13 locusts from the Ambagh and Hingol reks in May had the index: 92S:8T:0G: :61(6):39(7).

A collection of 69 specimens made in the Sheh-Lakhra outbreak centre in May-June showed the facies: *74S:23T:3G: :59(6):41(7).*

(c) *Sind-Rajputana area*

1. *Southern desert areas.* No locusts were met with in the neighbourhood of Chachro or anywhere in the Thar-Mallani areas in March, April and May.

The only individual noticed in southern Sind was a male with 6 eye-stripes, and yellowish wings and mauve base collected at Sehwan on 2 March, presumably a migrant. Another individual (with deep yellow wings) was observed at Kuri in south Jaisalmer on 15 March.

2. *Northern desert areas.* No locusts were found at Sardarshahr from March to May, while at Nokh, where large numbers were present up to mid-February, none were seen after 3 March till 13 May.

Small numbers were met with in the first fortnight of March in the Pugal-Rojri area, as also in east Jaisalmer, especially near Lathi where a small concentration was observed on 22 March. During April no adults were noticed anywhere in the Bikaner-Jaisalmer areas nor along the eastern fringes of the desert in the Ferozepur-Bhatinda-Hissar areas.

Spring breeding. On the other hand, fair numbers of hoppers were met with during April in Jaisalmer-Bikaner areas. Between 16 and 23 April, several (II to V instars) were found at Rojri, Pugal and Amarpura in west Bikaner; and between the 11th and 17th, 9 hoppers (I, II and III stages) at Lathi, Sihar and Phalodi in the east Jaisalmer areas. A V-instar hopper was found at Baru in east Jaisalmer on 18 May, another (also fifth-instar) on 19 May at Suratgrah and four more (II to V stage) at Anupgarh on the 20th, and quite good numbers of newly fledged adults were observed in May in many parts of Bikaner-Jaisalmer region. This would indicate that light, but wide-spread, breeding had occurred in March-April in the northern parts of the desert in the wake of the heavy showers of February.

As to the disappearance of locusts in March-April from the above areas, there is little doubt that migration had occurred. There is, however, little direct evidence as to the direction of migration. As locusts were not noticeable either in the north-eastern borders of the desert, such as Ferozepur, Bhatinda, and Hissar, or in the south (Jodhpur and Thar-Mallani areas), it is surmised that westward migration had occurred towards northern Sind and Baluchistan, and that the fairly heavy breeding noted in Kachhi and Bolan in May is to be traced to the above migrants.

As to the factors involved in this spring migration, the following data extracted from the Monthly Weather Report for 1937 would indicate that so long as the effects of the heavy showers of 11 and 12 February lasted, locusts remained in these areas, and that when desiccation set in and conditions of low humidity associated with a rise of temperature began to prevail, they would appear to have left them.

Monthly meteorological data for the period January-April, 1937 in the Bikaner area

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain in inches
	Mean Max. in degrees F.	Highest Max. in degrees F.	Date	8 A.M. Percent	5 P.M. Percent	8 A.M.	5 P.M.		
January, 1937.									
Sri Ganganagar. .	69·3	77	3, 4-i	71	32	Cm; SW;NW	NW;N;NE	2·9	Nil
Bikaner. . .	73·8	85	3-i	41	18	SE; S; Cm	W; Cm N; NW	2·2	Nil
February, 1937.									
Sri Ganganagar. .	72·0	84	8-ii	83	47	Cm; N; SE	N; NE;NW	4·5	1·54
Bikaner. . .	76·7	85	7-ii	63	28	E; NE ; SE	N;W;NE;NW	3·3	2·08
March, 1937.									
Sri Ganganagar .	82·0	90	22-iii	54	23	SE;NW;NE; E.	NE;N;SW	1·6	0·21
Bikaner. . .	95·4	95	22-iii	33	12	SW;E;SE	NW;SW;W	1·7	Nil
April, 1937.									
Sri Ganganagar .	93·0	107	16, 24-iv	47	29	E;SE;SW	NW;SW;W	1·7	·7
Bikaner .	97·3	106	16, 17-iv	25	9	SE;E;NE	NW;W;SW	1·2	Nil

The rise of temperature and fall of humidity in March-April at Bikaner are significant. In the Bikaner area, the direction of wind would appear to have been mostly easterly or south-easterly during the forenoons.

May migrants at Nokh. After an absence of over two months, locusts were seen again at Nokh from 13 May. In all 23 individuals were found, the population density being about 46 per sq. mile. Many had either transparent or light yellow wings, indicating a recently fledged brood, representing spring breeding in the northern desert areas. In addition, some individuals with yellowish wing with mauve or pink tinge at base were also noticed, which were presumably migrants either from Kachhi or upper Baluchistan. A similar population was noticed during the latter part of May in the Pugal-Rojri-Amarpura area in Bikaner and in the Baru-Nokh area in Jaisalmer.

34 specimens pertaining to this period had the index: *67S*:33T:*OG*: : *65(6)*:*35(7)*. No locusts were met with around Sardarshahr.

(d) *Kachhi Bolan area.* As surveys carried out in the Kachhi area in the earlier years showed that, as a rule, few locusts could be seen there except at the time of migration, no arrangements had been made for examining the area early in the year. When, therefore, Bhatia visited it in May to look for the early migrants from the west, he was surprised to find large numbers of green hoppers all over the area.

The Kachhi area is a great treeless level flat of the clay loam, mostly alluvial in origin. It is virtually an extension of the Sind alluvium wedged between the high hill ranges of Baluchistan, and receives the floods-waters of the great mountain streams debouching from the hills. Cultivation is limited to the fringes of the hills, wherever spring or stream water is available, or to areas which can be reached by flood-waters. After rainfall, water either collects in small depressions or runs along shallow channels off the surface of the plain, and wherever water soaks

into the soil, vegetation springs up and stands for a fairly considerable length of time owing to the retentive nature of the clay loam. Bhatia found the breeding taking place mostly in such situations, though hoppers were seen to a certain extent also in cultivated fields. As hoppers were present in the area from April to July, breeding was apparently continuous for over four months. Besides grasses, certain annuals were found springing up after rain, among which *Heliotropium eichwaldi* (locally known as *Popat*) was fairly abundant. Hoppers of the Desert Locust were found almost exclusively on this plant, whereas hoppers of *Locusta migratoria,* which were also to be seen in this area, preferred the grasses.

Fairly good general rainfall, varying from 2 to 4 inches in all, had been received in the Kachhi region between December and March in the winter of 1936-37, and had presumably provided conditions favourable for oviposition. Hoppers were met with in most parts of Kachhi, except in the Sibi-Lehri sections to the East.

Sibi-Mashkhaf area and the Bolan valley were examined in June and fair numbers of locusts as well as hoppers were noticed. At Kirtha in the Bolan valley (Pl. 19) large concentrations were noted among cultivation and the density of population was found to be as high as 17,760 per sq. mile. It might be mentioned here that *Locusta migratoria* ph. *solitaria* was also found breeding actively in the same area, and, in fact, in much larger numbers, the density being estimated to be about a million per sq. mile [Rao and Bhatia, 1937, p. 84]. In hill valleys like that of Bolan, cultivable areas are limited to silt patches deposited at the bottom between rocky hill-sides, and as, naturally, eggs can be laid only in such locations, crowded oviposition is brought about.

Hoppers of I, II and III instars were found in June at Thana Dasht and Spezand (6,000 ft. above sea level) in the upland valleys of Baluchistan not far from Quetta. They were collected on *Popat* (*Heliotropium eichwaldi* and *Chrozophora verbascifolia*), Sorghum and other plants. Collections of this period showed that the population consisted of yellow-winged adults of the old generation, some of which carried a few green algae on the wings as well as Tyroglyphid mites, that had apparently migrated from the Bolan valley into the uplands, with the advance of spring and the consequent development of conditions favourable for breeding.

The origin of the breeding in the Kachhi area. As no surveys had been made in the Kachhi area before May 1937, it is not possible to say when locusts began to appear in that region. From observations made in 1938, however, it may be surmised that they should have reached the area early in March, or possibly even in the latter part of February. In the absence of actual specimens, no statement can be made as to the affinities of the early migrants, but among the collections made in May by Bhatia, a few forms with deep yellow wings—evidently forms of the old generation—were found along with others with hyaline or light yellow wings—evidently recently developed. A fair number of the old brood carried green algae on the wings and *Tyroglyphid* mites on their bodies. Since forms with green algae had been noted among the collections made in January-March in Bikaner-Jaislamer areas, and also among those of Lasbela of December-March, as well as among the migrants found in February-March in the interior of Mekran and since *Tyroglyphid* mites had been noted on many locusts in the Bikaner and Lasbela areas in the autumn of 1936, it is surmised that the Kachhi infestation had originated from locust concentrations found in winter in parts of the Lasbela and north Rajputana areas. As rainfall occurred in November in the Rajputana

Plate 18.—*Camelthorn occurring as a weed in* jowari *field* : November 1937; Goth Safar Khan near Sheh Lakhra. Hoppers said to feed on camelthorn and other weeds.

Plate 19.—*Site of breeding at Kirthar in Bolan valley in June 1937* : Large numbers of hoppers of *Locusta migratoria* and *Schistocerca* were found breeding here in cultivation as well as outside.

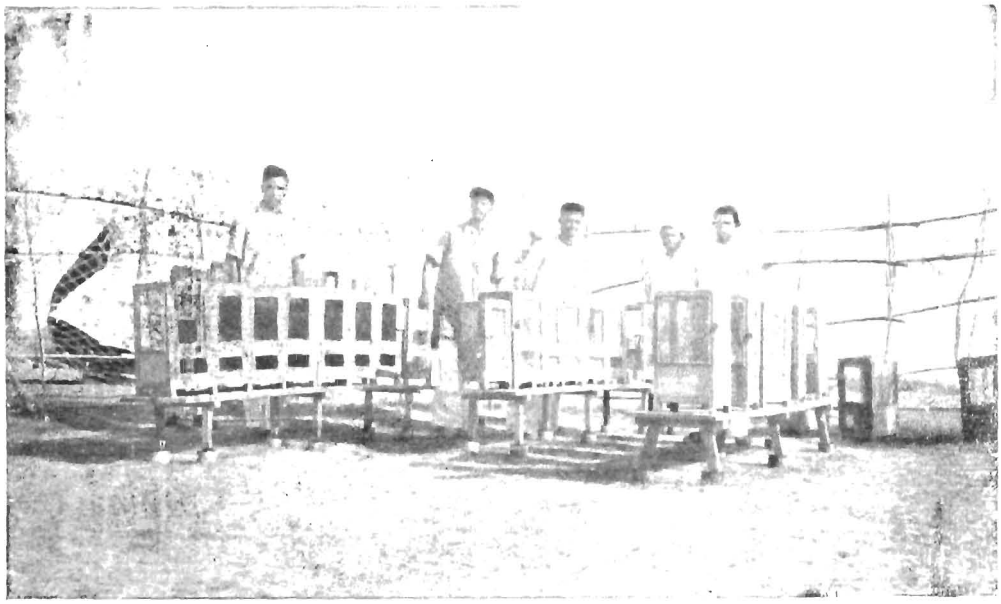


Plate 20.—*Breeding cages kept on low benches*, the legs are fitted wit ant-pans to prevent invasions of the cages by ants. Used at Pasni and Ambagh.

area, it is possible that a fair number of forms present in Rajputana during that period had become infected with colonies of green algae, and had subsequently migrated to the rek areas of Lasbela and Mekran in winter. By February-March, these had possibly migrated from the coast to the interior—(1) from the Mekran coast into the Mekran hinterland, and (2) from the Lasbela coast into the interior of Lasbela and thence into Kachhi. In addition, it is possible that the locust population found in Jaisalmer area in February had migrated directly into north Sind and thence into Kachhi.

The biometrical index of 21 specimens collected in the Kachhi area during May was 58S:42T:0G: :57(6):43(7).

Dera Ghazi Khan area. In the first fortnight of April, Taunsa, Tibi Kasrani and Dera Ghazi Khan were visited, and a single locust was found, but no hoppers. Examined again between 18 and 20 May, 25 hoppers (including all stages) and 11 adults were noticed near Dera Ghazi Khan. This indicates that light spring breeding had occurred as a result of fairly good rainfall.

III. Summer period 1937

(a) *Kachhi-Bolan areas.* Already stated, fairly good numbers of adult locusts and hoppers were found in the Bolan valley, Kachhi and Dasht-Spezand area in June, but considering the large numbers of hoppers noticed in May, the adult population met with in the Kachhi-Bolan area cannot be considered to have been proportionately high. As very high temperatures (maxima ranging from 119° to 125°F.) were being recorded at Sibi in the Kachhi area during May and June, and the humidity was as low as 18 per cent., it is surmised that most of the adult locusts were leaving the area within a week or two after acquiring wings. It was also observed that, in most cases, specimens liberated after marking rose high into the air and disappeared in an eastern direction with the prevailing wind.

Hoppers were still being found in parts of Kachhi till the middle of July, and fair numbers of adults were also being encountered owing to the change in the climatic conditions due to the influence of the monsoon. Hoppers were observed about the middle of August at Harnai and on the 24th at Bhag, and represented obviously the monsoon brood. Small numbers of adults were also met with in the Bolan, Harnai and Spezand areas, and in Kachhi.

The facies of 24 specimens collected in West Sind-Kachhi area in June-July-August 1937 was 60S : 40T : 0G : : 46(6) : 54(7).

(b) *Sind-Rajputana desert*

(1) *June*—1937 : *Appearance of summer migrants*

Thar-Mallani area. The first locust encountered since December 1936 was found at Chachro on 17 June, and in the Mallani area, on 18 June. Three more locusts were noted at Chachro during the month. Most of these possessed bright to light yellow wings with pink or mauve at the base.

Sardarshahr area. At Sardarshahr the first locust of the summer season was noted on 23 June and six more were collected by the end of the month. To the west of Sardarshahr, two locusts were found on the 11th at Surpura and another on the 15th at Punrasar. Some of these also had a touch of pink or mauve at the wing-base.

Nokh area. Large numbers of locusts were being encountered around Nokh throughout June, the average density for the month being about 260 per sq. mile. Fairly good numbers were also met with in the eastern

parts of Jaisalmer between Mohangarh and Nokh. Most of them had yellow wings with a tinge of pink or mauve.

The facies of a collection of 58 specimens from the Sind-Rajputana area during June was 53S:45T:2G:76(6):29(7).

The following indices were noted for populations found on the western reks during June:

Ambagh reks: (11 specimens): 73S : 27T : 0G : : 55(6) : 45(7).

Mekran reks. (41 specimens): 71S : 29T : 0G : : 51(6) : 49(7).

Most of the locusts on the Ambagh and Mekran reks exhibited pink or mauve wing bases and were evidently all immigrants there being no spring breeding on the coast, owing to lack of rainfall.

The origin of the summer migrants

As a certain amount of breeding had occurred in the interior of Mekran, as in Kolwa and Rakhshan, some of the migrants found on the coast might have been derived from these areas, but it is not unlikely that others had come from beyond the Baluchistan borders. In the Jask area, more rain had fallen in March than on the coast of British Mekran and it is not improbable that in the interior of Iranian Mekran also rainfall had, as in the British areas, been followed by breeding.

Again, records indicate that heavy winter precipitation had occurred in the Sharjah-Muscat area. Indeed, heavy showers had fallen at Sharjah as early as November, and good rain even in February. Whereas in previous years no observations had been made by any entomologist in this area, information on breeding in the Oman area recorded by Maxwell—Darling (1937) is available for February-March 1937. In the first fortnight of February 1937, about 20 green hoppers of the 4th and 5th instars were found on sandy ground near Sohar on the Batina coast of Muscat, indicating egg laying in the later part of December and hatching early in January. Several sexually mature locusts (mostly *in capula*) were seen in March on the Bareimi plain in the interior of the Trucial Coast. Presumably these had developed locally and represented the first winter brood (November-January). In the absence of observations, one can neither say with certainty wherefrom the parent locusts had reached the Oman areas, nor make any statement about the movements of the new generation. As, however, locust swarms are known to have flown across the Straits of Hormuz and parts of the Gulf of Oman in 1929, the writer is inclined to believe that the numerous migrant locusts that were present on the Ormara and Pasni reks in November-December 1936 and had later on disappeared, had in great part migrated westwards, in the direction of Iranian Mekran and possibly also across the Gulf into Oman territory. For the *'Gorich'* or the north-east wind of Mekran, with which autumn migrations of the locust are usually associated, blows across the Gulf and reaches the Oman coast as the *'Nashi'* and quite possibly individual locusts may be carried across the sea by these wings. During times of mass-multiplication, instances are known of locusts being encountered by ships in mid-ocean, and in one authentic case observed by Mr. T. Bainbrigge-Fletcher on 13 October 1930, a specimen of the Desert Locust—of pink colour and *gregaria* phase—was collected on board S. S. Morwada at 4 P.M. 240 miles off the Laccadives and at least 500 miles from the nearest shores of the Indian mainland. Since Predtechensky (1935-b) has recorded the entry of locust swarms into Iranian Mekran from the Oman coast at the end of March 1931, it should not be considered unlikely that some of the *solitaria* locusts, known to have bred in the Oman area in January-February had migrated into Jask area and thence into British Mekran later on.

In the Lasbela and Karachi areas, the migrants may have been derived to some extent from the Sheh Lakhra outbreak centre, but as some of the individuals collected at Sheh Lakhra were themselves found to have mauve tinge at their wing bases, there is little doubt that such forms were migrants from further west. In the Rajputana area, the great majority, of the migrants were probably from the Kachhi-Bolan area, relatively few being from the western areas.

(2) *July-August* 1937.—*Summer breeding.—Monsoon rainfall.* The influence of the monsoon was felt in the desert from about 23 June, when fairly good showers were received in parts of eastern Rajputana, such as Sadulpur and Jhunjhunu. In July, rainfall was widespread in the desert and on the whole fairly heavy; but in north-east Jaisalmer and north-west Bikaner—in an area enclosed between Bap, Nokh, Mohangarh, Barsilpur, Pugal, Anupgarh, Suratgarh and Mahajan, rainfall was comparatively low during July.

August proved to be a dry month throughout the Gujarat-Rajputana area, but in eastern Rajputana a few light falls were recorded at the end of the month. During the second week of September, fairly good falls were received throughout the desert and in Gujarat.

Northern desert areas.—Distribution of locusts in July. At the end of June and in early July, fairly large numbers were seen in the Nokh-Baru and Pugal areas. At the Nokh Outpost the average density during June was as high as 260 per sq. mile, but owing to lack of rainfall the population was found gradually decreasing till at the end of July, no locusts were noticeable around Nokh. The average for the month was only 77 per sq. mile, but hoppers of 1st to 4th instars were observed, indicating the occurrence of light breeding. Similarly few locusts were met with during the latter part of July and the beginning of August in the high dune areas of Barsilpur, Pugal and Rojri, but a few hoppers of different instars were found between Pugal, Rojri and Anupgarh during the first week of August. A recently fledged adult—the earliest of the season—was also obtained near Rojri on 7 August, from which it is clear that oviposition had in this case occurred as early as the third week of June.

On the other hand, at Sardarshahr where no locusts were seen till 23 June, fairly good numbers were found to have appeared by the end of the month, the average density for the month being 36 per sq. mile; and during July there was a further increase of population, the density being about 92 per sq. mile. Hoppers of different instars were also detected towards the close of July. Similarly locusts were found appearing in the eastern parts of Bikaner by the last week of June. About 9 July, Bhatia noticed fairly large concentrations of locusts—ranging from 5,000 to 10,000 per sq. mile in density—between Reni and Sadulpur in east Bikaner At the time of examination, he also found at some places, especially Nohar, Reni and Sadulpur, quite large numbers of solitary phase individuals of *Locusta migratoria* and in some cases, as at Sadulpur, the concentrations were very much denser being as high as about 89,000 per sq. mile. *Locusta* was, however, found in moist situations at the bottom of the valleys, while the desert locust was present under drier conditions among the sand mounds. Subsequent visits paid to areas south-east of Sadulpur indicated that similar concentrations of *Locusta* and *Schistocerca* had occurred in the Shekawati area of Jaipur State early in July.

The eastern parts of the desert—consisting of the Nohar-Reni-Sadulpur area of the Bikaner State (known as the Bagar country) and the Pilani-Jhunjhunu-Sikar area of the Jaipur State (the Shekawati desert) form

a fairly level sandy area with a few scattered, low sand dunes. As this area usually receives comparatively more rainfall than the country to the west, most of it is cultivated with *bajri* (spiked millet), *til* (sesame) and *moong* (pulse) and trees are fairly common. As there was early and fairly heavy rainfall in these areas, most of the population found in the east Jaisalmer and west Bikaner region during May and June would appear, as a result of drought there, to have gravitated into the eastern areas. Egg-laying by both *Schistocerca* and *Locusta* would appear to have followed. Large numbers of hoppers were apparently to be found in these areas, and those that were present among fields of crops were recognised by the cultivators as *Phidkala* (a name applied indiscriminately to hoppers of any kind attacking crops).

Breeding July-August. General breeding of the desert locust was observed all over the northern desert areas wherever sufficient rain had fallen, but, as already mentioned, it was heaviest in the eastern parts. Large numbers of the new generation adults began to appear during the latter part of August, resulting in a great increase of population. In parts of the Shekawati area—between Pilani and Jhunjhunu—it was estimated that the density was as high as 200,000 per square mile about 19 August. The hoppers were feeding mostly on the following plants: *Indigofera cordifolia* (*Bekkar*), *Tephrosia hookeriana* (*Maso or Bishani*), *Tribulus terrestris* (*Kanti*) and *Aerua tomentosa* (*-javanica*) (*Booh*).

Locust movements in August. Owing to lack of rainfall during August in the Rajputana area, the ephemeral monsoon vegetation was observed to be drying up, with the result that locusts were forced to concentrate in fields of bajri, where the density of population tended to be very high. With the prevalence of drought throughout August, a gradual rise of temperature and a fall of humidity were observable in most parts of the desert,—conditions very unusual for a mid-monsoon month like August. High maximum temperatures up to 105°F. were reached at the end of the month and these acute climatic conditions continued till 7 September. Such adverse weather conditions were apparently not liked by the dense adult population found in these areas, so that migratory movements were set afoot much earlier than usual. During the second fortnight of August, the occurrence of several dust or thunder-storms was noticeable in the desert areas in the afternoons, and the heavy winds from the north-east, generally associated with such storms would appear to have been instrumental in transporting them to distant areas.

At this time it was reported that some of the townsmen of Sardarshahr had noticed a small loose swarm of grey-coloured locusts flying over the town at a height varying from 100 to 500 feet above the ground at about 6-15 P.M. on 23 August and it was stated that a severe dust-storm from the north-east was also noticed at that time. An increase in the local locust population around Sardarshahr was noticed on the following day, but in spite of all efforts made in the course of the following week, no trace of any actual swarm movements could be found, and it is probable that the swarm in question was, in reality, a large number of solitary individuals, which had under the excitement of an in-coming thunderstorm taken wing simultaneously and flown with it into fresh locations. Investigations made at this period showed that in the areas to the north-east, such as Reni, Sadulpur and Hamiriawas, there was a definite diminution of locust population at this time, which was attested to by the cultivators, and also an increase in numbers towards the west and the south-west at the same time, as could be deduced from the results of surveys made in these areas and around Nokh at the end of August.

At the Nokh Outpost, with the exception of small numbers of hoppers, no locusts were met with during the first fortnight of August. During the third week, a few adults of the new generation were found in the course of surveys, but from the 25th onwards a sudden rise in the local population (about 2,000 per sq. mile) was noticed, the locust individuals being mostly yellow-winged. The average density, thus, rose from 77 per sq. mile in July to 242 in August. There is apparently little doubt that the rise was due to an immigration from outside.

Southern desert areas. There was good rainfall in most parts of the southern areas in July, and fairly extensive breeding occurred in the Thar area of Sind, in the Mallani-Sheo areas of Marwar and in the Mayajlar area of south Jaisalmer during July-August.

At Chachro, locusts began to appear at the end of June and were found in fairly large numbers during the greater part of July, when egg-laying apparently also occurred. Few locusts were seen at the close of the month or even during the early part of August, but by the middle of the latter month, forms of the new generation began to appear and by the end of the month the population had greatly increased. On the 27th, for instance, about 137 locusts were met with in the course of two hours indicating a density of about 11,000 per sq. mile. Fair numbers of hoppers of the 4th and 5th stages were also found.

Extensive breeding had apparently occurred all over the Thar and Mallani areas and numbers of adults of the new generation were found everywhere, and particularly near Barmer, between Gadra and Khisar, between Khisar and Chachro and between Chachro and Sil. Few locusts however, were found roundabout Chelar in western Thar in August, where little rain had fallen and breeding had not occurred.

At Barmer, quite a large locust population—estimated at about 40,000 per sq. mile in density—was found on 23 August, and as most of them had yellow wings, it is surmised that this was the result of an immigration from outside with the development of drought conditions in regions further east.

Biometrical index of the population in the desert

July 1937.—*Northern desert areas.*

East Bikaner area.—(55 specimens): 61S : 35T : 4G : : 76(6) : 24(7).

West Bikaner and East Jaisalmer area.—(38 specimens): 79S : 21T : 0G : : 73(6) : 27(7).

Southern desert areas.—Thar-Mallani area.—(40 specimens): 61S : 39T : 0G: : 73(6):27(7).

The population found in the desert areas in July appears to have been more or less homogenous, consisting mostly of the original summer migrants.

August 1937.—*Northern desert areas.*

East Bikaner area.—(131 specimens): 56S:40T:4G: :77(6):23(7).

West Bikaner and East Jaisalmer area.—(69 specimens): 64S : 36T : 0G : : 74(6) : 26(7).

Southern desert areas.—Thar-Mallani area.—(69 specimens): 43S:53T: 4G : : 96(6) : 4(7).

The population found in East Bikaner and Thar-Mallani areas in August was made up almost entirely of forms of the new generation, as good breeding had taken place in these areas, while that of West Bikaner

and East Jaisalmer area only partially consisted of forms of the new brood, as there was not much breeding here by reason of a too deficient rainfall.

It was rather remarkable to find that most of the new generation forms noticed in August in the Thar-Mallani areas—males as well as females—had six eye-stripes. Individuals with seven stripes were first met with only at the end of the month. On the whole, six-stripped forms were noticed to preponderate in the first monsoon brood in the desert.

(c) *Lasbela-Karachi Area.* In June, a few locusts only were met with during the first fortnight, but during the second fairly good numbers were noticed. Many of them had yellow wings, and some had pink or mauve tinge at the wing-bases. The average density for June was 69 per sq. mile, as compared with 15 for May. Around Karachi only a single locust was found (24 June), but it is significant that it had a touch of mauve at the wing base. Between the 18th and the 24th July fairly heavy showers amounting in all to 3·09 inches were recorded at Ambagh, including a sharp fall of 1·47 inches on the 21st, and at Karachi heavy falls, totalling about 8 inches, occurred at this period. During July, fair numbers of locusts—mostly with bright yellow wings—were noticed during surveys on the Ambagh-Sonmiani reks. Most of them were apparently mature and pairing was observed. Sand-grains were noticed sticking to the ovipositors of some females as early as 8 July, and egg-laying was obviously common after the heavy falls of the third week. Towards the end of the month, some forms with pink and mauve wing-bases were met with. The average density during July was about 159 per sq. mile. In the Karachi area, several locusts were found during July on the banks of the Hab river, along with specimens of *Locusta.*

Fair numbers of locusts were met with during August, only yellow-winged individuals were seen in the first half, but from 15 August, the new generation with hyaline wings was also noticed. Quite large numbers of hoppers were found in many parts of the rek area. In the Hingol region, few locusts were seen in the Pohr-Chandragup-Hingol areas, but quite good numbers of both locusts and hoppers in the Khandewari-Kanbarar-Nakhetri areas. The hoppers were of all stages, found mostly on *Maikh (Tribulus terrestris)* and *Booh (Aerua).* Good breeding was observed also in the Sheikhraj area of Liari and near Uthal, as also in the Goth Sherkhan area. The average density for August was estimated at 132 per sq. mile. In the Karachi area, locusts were found mostly near Band Muradkhan along the sandy banks of the Hab river. On the 20th, more than a dozen newly fledged ones (all six-striped) were collected, as also good numbers of fresh *Locusta* adults. Apparently egg-laying had occurred soon after the first showers of July.

Biometrical index.—Lasbela area:

June 1937.—(19 specimens): 74S: 21T:5G: :53(6):47(7).

July 1937.—(37 specimens): 65S:35T:0G: :57(6):43(7).

August 1937.—(57 specimens): 70S:25T:5G: :58(6):42(7)

The August population found included a fair percentage of the new generation.

In the case of the July population, five specimens collected on 8 July on Guruchela reks and two on the 4th at Naka-Kharari carried numerous green algae on the wings. Most of these had bright yellow wings and were presumably old forms, but two had light yellow wings and carried only a few young colonies.

(d) *Mekran area.*—(1) *Mekran coastal reks.* Apparently the light immigration of forms from the interior continued during June and July on the reks, as fair numbers were met with on the Pasni and Gwadar reks. In the Ormara area, however, comparatively few locusts were observed, and the following are the figures of relative density during summer:

Areas	June	July	August
Ormara	14	9	7
Pasni	46	94	32
Gwadar	22	42	22

Most of these specimens had light to deep yellow wings, and many had pink or mauve bases. Four of them collected on 7 and 19 June at Pasni had yellow wings and colonies of green algae; wing-bases were also mauve-tinged. Two yellow-winged specimens found in July on the Pasni-reks also had a few algal colonies, as also two more collected on Sanjar rek at Pasni on 7 and 21 August. Similarly one specimen with a few algae was found at Gwadar on 3 July, and another with quite a number of algal growths on 3 August. It is, therefore, probable that most of summer forms were migrants from the interior of Mekran, and that the yellow-winged ones carrying the green algae were parts of the old generation known to have been present in spring in the Kolwa-Balgattar areas. The decrease of population noticed in August on the reks is presumably due to emigration.

Biometrical index for the summer months. The populations found on the different Mekran reks during June and July consisted of immigrants and were, on the whole, homogenous. They had the following facies: (112 specimens): 70S:30T:0G::54(6):46(7).

The August population was comparatively low, but the facies is more akin to that of September: (33 specimens) 59S:37T:4G: :67(6):33(7).

(2) *Mekran interior.—Kulanch-Dasht area.* In June, a few hyaline-winged locusts were met with in Kulanch, apparently developed from hoppers found in the Nokbur-Ban areas in May. In July none was noticed in Kulanch during a survey tour, but between the 18th and the 23rd, seven specimens were collected in the Dasht area. Their wings varied in colour from a light to a bright yellow. As dust-storms had prevailed during this period, it is likely that they had been transported into the Dasht area from elsewhere, as was observed to have actually happened in Kolwa during this period. In August, no locusts were found anywhere in Kulanch and Dasht.

Panjgur area. During the first week of June, seven green hoppers (2nd to 5th instars) were collected on Kapochisk *(Chrozophora)* plants at Gar, in the same area where incipient swarming had occurred in June 1935. On the 11th June, a clear-winged adult and a IV-instar hopper were found in a jowar field at Kohni-Kalat near Panjgur. During the third week, about a dozen hoppers (I to III stage) and one yellow-winged and two hyaline winged adults were collected at Nag-i-Kalat in the Rakshan valley. Early in July, two hoppers (IV and V instar) were observed at Saradak near Panjgur and one V-stage hopper at Gar (8 July)—all on *Kapochisk* plants, indicating early summer breeding in the hinterland—as in 1935, the hoppers possibly representing the second spring generation. A few locusts were met with at Nag-i-Kalat during August, but no hoppers.

Kolwa area. In June no locusts were seen in the Hoshab-Rodkan area. In July, a fieldman touring in Kolwa did not find any (14 to 18 July) between Hoshab and Chambar-Kalat and owing to severe thunder-storm rain-fall on the 18th and the 19th, had to make a forced halt from the 19th to the 22nd at Chambar-Kalat. On the 23rd, he found concentrations of yellow-winged locusts between Chambar-Kalat and Goshanak, 35 forms being observed with a density of about 1,400 per sq. mile. As none had been seen by the local people in this area prior to rainfall, they had obviously been conveyed into Kolwa from the east by the storms themselves. More locusts were seen at Awaran and again between Awaran and Godri. As freshly moulted adults were later on found here in September, egg-laying had evidently followed the fall of rain mentioned above. Specimens preserved indicate that the population was mostly *solitaria* with a fairly high percentage of seven stripes.

IV. Autumn season, 1937

(a) *Sind-Rajputana area*

(1) *Northern desert areas.* At Sardarshahr, which is mostly a region of bare, shifting sand-dunes, the locust population was, on the whole, low, but in villages three to five miles roundabout, such as Bikamsar, Mitasar, and Harpalsar, good concentrations were noticeable in *bajri* fields. At the beginning of September, populations as high as 15,000 to 20,000 per sq. mile were noted roundabout Sardarshahr, as well as at Baleri and Reni. At Narwasi, especially, calculations indicated concentrations as high as 200,000 to 300,000 per sq. mile on 4 September. In most of these places, adults of *Locusta* were found in association with those of *Schistocerca* and were generally present in comparatively larger numbers.

By mid-September, however, a perceptible diminution of population was noted in most of these places. In the Shekawati, area, where very large numbers had been found in August, none was noticed in September; similarly also, none in the Loharu-Rewari areas. By the first week of October, very few were seen at Sadulpur, Reni and Narwasi. In western Bikaner (Mahajan, Sonpalsar and Pugal), locusts were numerous during September, but by mid-October, they had diminished in numbers and few were seen in November.

A study of the comparative population density at Nokh and Sardarshahr during the autumn months clearly points to a fluctuation in numbers apparently due to emigration.

Average population density per sq. mile

Outpost	September	October	November
Sardarshahr	1,433	127	132
Nokh	1,044	154	45

Breeding. The fairly heavy showers received in September, had led to some amount of breeding in the Sikaner area. Hoppers were seen round about Sardarshahr throughout October, as well as in the Reni, Sadulpur, Mahajan, Nohar and Girasar areas, but only in small numbers. During November, a few hoppers were being found at Nokh, Sardarshahr and Malkisar and most of the adult locusts noticeable in the Bikaner area, had transparent or light yellow wings representing the second monsoon generation, the individuals of the first brood having apparently migrated from the area.

Plate 21.—Desert Locust : Solitary phase adults :
Fig. 1. Young locust with hyaline wings : Fig. 2. Young locust with hopper markings still visible on pronotum; Fig. 3. Light yellow colour on wings ; Fig. 4. Mature locust with bright yellow wing-colour

Biometrical facies of the autumn population

The following were the biometrical facies of the autumn population in the northern areas:

September 1937.—(130 specimens) 55S: 43T: 2G::64(6): 36(7).

October 1937.—(74 specimens) 68S: 32T: 0G::53(6): 47(7).

November 1937.—(15 specimens) 60S: 40T: 0G::46(6): 54(7).

The second brood apparently had a higher proportion of *solitaria* and 7-striped forms than the first.

Whereas in 1936 several specimens with 8 eye-stripes were found in nature, during 1937, only one form was observed, which it is interesting to note, was collected on 3 October at Girasar from the same area—West Bikaner—where 8-striped forms had developed in nature during 1936.

(2) *Southern desert areas.* The increase of population noticed at the close of August in the Gadra-Chachro area due to the influx of forms of the new brood continued even during the first week of September. At Chachro the average density was found to be over 11,000 per sq. mile, but with the passage of a depression from the east across south Sind on 10 September, there was a sudden drop in density, the average for the second week being only about 3,000 per sq. mile. As almost simutaneously a sudden increase of population was noted at Ambagh, it is surmised that in the wake of the Bay depression, an influx of locusts from the Rajputana desert into the Lasbela area had occurred.

Similarly at Barmer, though large numbers were noticed during the last week of August, few were seen on 23 September, as also, very few in Mallani and south Jaisalmer by the end of September. On the other hand a rise of population was noticed at Chachro during the later part of September, the average density being nearly 6,000 per sq. mile. In October, a gradual decrease was noticeable, the average for the first, second and third weeks respectively being about 2,400, 1,700 and 850 per sq. mile, but during the last week as also in November, there was a rise due to the appearance of the second generation forms in the Thar area, the density for November being 2,391 per sq. mile. In December the average had dropped to about 1,170 per sq. mile.

By the middle of October, while, very few locusts were noticeable in Mallani and south Jaisalmer, they were apparently present in October and November in greater or smaller numbers in most of the Thar area, the population being mostly recently fledged forms. On 23 October, a concentration of about 60,000 per sq. mile was noted at Khokhropar, north of Chachro, though by 15 November very few were found at this locality. On the other hand, on the 18th November a concentration of over 35,000 was noted between Gadra and Parna also to the north of Chachro. Obviously these were cases of local migration.

Breeding. With the fall of about two inches of rain in many parts of Thar in September, there was a second instalment of breeding in these places. As the September population consisted mostly of the first brood produced in August, the hoppers emerging from the Setember oviposition clearly represented the second monsoon generation. Hoppers were observable in many parts of Thar during October and November, and a few even up to the end of December. The first adults of the second brood appeared by the end of October, and during November most of the locust population, as already stated, was made up of the new forms. Apparently most of these over-wintered in Thar.

Meteorological data connected with autumn migration

Owing to the unusually dry conditions prevalent in the desert in August, locust movements would appear to have commenced very early in 1937. In September, further migration had apparently been brought about by the agency of storms connected with a monsoon depression.

The usual type of autumnal migration was in operation during October with the development of drought.

After the setting in of cold weather by the middle of November, there were, apparently, few locust movements.

The following data extracted from the Monthly Review for 1937 of the India Meteorological Department would indicate the general climatic conditions that prevailed in the desert areas during the period—August to November 1937.

Monthly Meteorological data for the period—August to November 1937—West Rajputana

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain
	Mean Max. in Degrees F.	Highest Max. in Degrees F.	Date	8 A.M.	5 P.M.	8 A.M.	5 P.M.		
				Percent	Percent				(inche)
August, 1937.									
Sri Ganganaga	101.1	105	20,27,28	62	36	SW	SW; W	0.4	Nil
Bikaner.	98.4	104	20-viii	64	36	SW;W;S	SW;S;W	1.2	Nil
Jodhpur	94·8	99	20,21,26	73	45	SW;W;S	SW;S;W	6.9	Nil
Barmer	92·1	97	20-viii	74	46	SW;S;W	SW;S;W	6.1	Nil
September, 1937.									
Sri Ganganagar	99·3	105	6, 7-ix	59	32	SW; S; W; NE	W;NW;SW; N	2.3	0·34
Bikaner.	98·3	105	7-ix	65	38	SW; W	SW;SE;N; NE	8.1	0.82
Jodhpur	95.6	102	8, 30-ix	72	45	SW;W;NE; Cm.	SW;S;W; NW	5.7	3.87
Barmer	94.1	102	8-ix	74	54	W;NW;Cm; SW	SW;S;W	8.4	1·51
October, 1937									
Sri Ganganagar	93.5	102	2-x	46	24	SE;S;SW	NW;NE;Cm; W	0.5	6.11
Bikaner.	95·7	105	9-x	49	22	SW;SE;Cm; W	NW;SW;NE;	0.5	Nil
Jodhpur	96.4	108	8-x	42	17	Cm;NE;SW	SW;W;NE	0.3	0.01
Barmer	96.6	105	7, 8-x	53	26	N;SE;Cm; NW	SW;NE;W;	0.5	0.15
November, 1937.									
Sri Ganganagar	83.5	93	8, 9-xi	56	34	Cm;NE;E	NW;Cm;N; NE	9.8	Nil
Bikaner	86.6	95	9-xi	47	26	Cm;SE;S	NE;NW;Cm; N	1.1	Nil
Jodhpur	89.9	97	7,8,10-xi	36	17	NE;Cm;N	Cm;NE;NW; N	1.8	Nil
Barmer	90.2	99	8-xi	44	24	NW;N;Cm	N;NW;Cm	0.9	Nil

From the above, it may be seen that in August high temperatures and comparatively low humidity prevailed in the latter part of the month, and in the first week of September, especially in the northern areas, where cloud amount was also conspicuously low. Although the dominant winds were from south-west, observations made indicate that locust movements are associated mostly with north-east winds accompanying dust or thunder-storms. With the occurrence of storms connected with the depression of 9 September, movements of locusts towards the south-west would seem to have been brought about. Conditions of drought and high temperatures, that developed at the close of September with the withdrawal of the monsoon and continued into the middle of October, gave rise to the usual autumn migrations. Towards the end of November, winter conditions apparently set in.

Observations made on the movements of *Locusta migratoria* ph. *solitaria*—which was found breeding in association with *Schistocerca gregaria* in most parts of the desert—showed that this locust had also reacted similarly to climatic conditions (Rao and Bhatia, 1939).

Biometrical facies of the autumn population in the Southern areas.

September 1937.—(80 specimens) 49S : 47T : 4G : : 85(6) : 15(7).

October 1937.—(40 specimens) 62S : 36T : 2G : : 46(6) : 54(7).

November 1937.—(81 specimens) 64S : 32T : 4G : : 85(6) : 15(7).

The presence of a small element of *gregaria* in the population and the general preponderance of *six-striped* eyes in the southern areas, as compared with that of the northern, is somewhat noteworthy.

(b) *Kachhi-Bahawalpur-Dera Ghazikhan areas.* Bahawalpur and Khairpur were examined during September, Dera Ghazi Khan during October and Kachhi during November. In September, hoppers of different stages as well as a few adults were met within Bhawalpur territory at Rukanpur near Mithra and at Derawar during the last week. As hoppers were found at this time also at Rojri, some breeding had obviously occurred in the border areas of Bikaner also. Adults with hyaline or light yellow wings were collected at Akro on 9 and 10 September indicating the occurrence of light breeding in the Khairpur area. In October, small numbers of adults were found in the Dera Ghazi Khan area as well as 17 hoppers of different stages on *Booh (Aerua)* on the 8th at Tibbi Kasrani, indicating light breeding. Kachhi was not examined during September and October, but early in November several clear-winged specimens were met with at Gandhawa and Bhag as also a fair number of green hoppers of 2nd to 5th stage on *Popat (Heliotropium eichwaldi)* in cultivated fields at Gandhawa. Light breeding had probably been taking place during August, September and October in favourable situations in this area.

(c) *Lasbela-Karachi areas—Lasbela area.* During the first week of September there was a numerical increase mostly due to the appearance of a locally developed brood. The average density for the week was 711 per sq. mile. From the 9th onwards, coinciding with the appearance of thunderstorms, a sudden increase of population was noticed on the Ambagh reks. The average density for the second, third and fourth weeks was about 2,300, 2,900 and 2,000 per sq. mile respectively. The locusts found at this period had light yellow wings generally with pink or mauve wing bases, and in many cases also carried red mites. The rise of population on the Ambagh reks is significant in view of a simultaneous decrease in numbers noted in the Thar-Mallani area about the middle of September.

In the Hinidan area, a fieldman found a few locust at Kila, Hinidan and Hab-Chowki along the Karachi border between 31 August and 7 September. They had mostly light yellow or hyaline wings with pink or mauve at base and also carried red mites; and were obviously migrants.

A fairly high locust population was met with during October on the Ambagh rek areas, the density being about 1,900 per sq. mile. Most of them had pink or mauve wing-bases and carried red mites, while some were infested by Tyroglyphid mites. They were mostly migrants, though a certain proportion were obviously locally bred ones. In the early half of October, quite large numbers were encountered in the Hingol area, especially at Khandewari, Nakhetri and Pohr. Hyaline-winged individuals (presumably locally bred) were seen in fair numbers, especially in the Khandewari area, but the majority were apparently migrants with mauve or pink wing-bases. The concentrations reached a density at places of 4,000 per sq. mile, but the average for the whole area was about 2,200.

Breeding. Hoppers were observed in some numbers in parts of the Ambagh rek during September and October and a few even in November. Good breeding was noticed in the Liari-Sheikhraj areas and in the Jankar Kaur area near Nakhetri, in the Bhawani Nadi area near Lak Badok and also roundabout Uthal in the early half of October, hoppers being found mostly on *bosiri* (*Indigofera cordifolia*), *maikh* (*Tribulus*) and *booh* (*Aerua*) and in *bajri* fields.

In November, the population had greatly diminished in numbers, the average density being only about 980 per sq. mile in the Ambagh area. in the middle of November, small numbers of locusts of a migrant character were found at Thana Kila and at Pabuni. Large concentrations of *Locusta migratoria* ph. *solitaria* were detected at this time in *jowar* fields at various places, such as Hassan Pir, Thana Kila, Hinidan, Pabuni and Goth Sher-Khan, and also at Naka-Kharrari and Lak-Baduk in the rek areas, and there is strong presumptive evidence to indicate that these had been derived from breeding areas in the Sind-Rajputana desert (Rao and Bhatia, 1939).

Karachi area. In September, several locusts were observed at Band Muradkhan and opposite Hab-Chowki along the banks of the Hab River. Some had hyaline wings and were probably locally bred, but the rest had mauve or pink patches being evidently migrants.

In October and November, the large stretch of stony desert area across which the railway line from Hyderabad (Sind) to Karachi runs was cursorily surveyed. The eastern part of this stretch is crossed by a few limestone hills forming the outlying spurs of the Thano Bulakhan ranges, while the western part—towards the Karachi end—is more or less flat and is covered by low scrub growing on a coarse sandy loam. This area is traversed by the generally dry beds of watercourses carrying the drainage from the Thano Bulakhan hills. It was noticed that few locusts were present outside the sandy beds of the rivers such as for instance, the Baran, the Kalu and the Malir, where they were usually seen feeding on sedges and other wild plants. Specimens collected in these situations had mauve, pink or bluish bases and were presumably in the process of migration. In the latter part of November and in December, however, locusts were not met with, migration having probably ceased by that time Observations made would indicate that locusts migrate in stages, making

a series of short hops covering about a dozen miles at a time. They probably, alight wherever they discern a sandy patch carrying vegetation, as for example, on the beds of water-courses, for feeding and taking rest. and then move on again.

As in the Lasbela area, *Locusta* was found in some numbers in *jowar* cultivation near the Hab river and also at Jhimpir and Thano Bulakhan in the latter part of November.

Biometrical facies of the population.

September 1937.—*Lasbela area.*—(14 specimens) 47S : 43T : 0G : : 64(6) : 36(7).

Karachi area.—(35 specimens) 49S : 43T : 8G : : 71(6) : 29(7).

October 1937.—*Lasbela area.*—(237 specimens) 51S : 46T : 3G : : 74(6) : 26(7).

Karachi area.—(42 specimens) 59S : 41T : 0G : : 69(6) : 31(7).

November 1937.—*Lasbela area.*—(41 specimens) 63S : 34T : 3G : : 61(6) : 39(7).

Karachi area.—Only four specimens collected.

In this connection the resemblance of the facies of the Thar-Mallani population in September, *viz.* 49S : 47T : 4G : : 85(6) : 15(7), to that of the Karachi area for September, and that of the Lasbela area for October is somewhat striking. There is a similar resemblance between these and the facies of the Mekran population in September, October and November 137, and the similarity is probably due to a homogeneity of the populations.

(d) *The Mekran area.*—(1) *Mekran interior*

Panjgur-Kech-Buleda areas. No locusts were met with in September except for one specimen from Turbat on the 29th in a *jowar* field. In October, a male locust with yellow wings and mauve base was found on the 11th between Sohrap and Panjgur, as also a fifth instar hopper on *Gandhil (Dactyloctenium)* grass at Sarwan, indicating stray breeding in late summer.

Kolwa-Balgattar area. In the course of a tour (11 to 29 September), locusts were encountered between Awaran and Goshanak, between Goshanak and Chambar-Kalat, and roundabout Chambar-Kalat and Rodkhan, seen in concentrations of the density of 500 to 2,000 per sq. mile. Many of these were found among cultivation. Some had hyaline wings and represented presumably a brood developed locally following July rainfall. The majority, however, possessed yellow or light yellow wings with mauve or pink at base, indicating migratory activity. These locusts had possibly been conveyed into Mekran by thunderstorms accompanying the depression of 10 September over Sind, as had happened in the Ambagh Area at about this period. A few were also noted at Dasht-Shahbaz and Gar at the end of September.

In the Kolwa area, no locusts were noticed, in October, nor were any found in November except for two specimens with pink wing-base collected between Goshanak and Chambar-Kalat on 6th.

Kulanch-Dasht area. In September, none was observed except for a yellow-winged female found at Sardasht on the 29th. In October, several locusts were met with at Ban, Nokbur and Sardasht in Kulanch and at Kuhak, Hasadi and Suntsar in Dasht. The colour of the wings varied from hyaline to yellow and many showed a tinge of mauve. In November also, fair numbers with mauve wing-bases were noticed, especially, between Nokbur and Sardasht on the 3rd.

Biometrical facies of the population. In September locusts were met with mostly in Kolwa and the following was the index: *September* 1937 (35 specimens) 62S : 31T : 7G : : 74(6) : 26(7).

In October and November, few locusts were found in the interior of Mekran except in the Kulanch-Dasht Area, showing the index:—*October-November* 1937.—(20 specimens) 53S : 42T : 5G : : 95(6) : 5(7).

(2) *Mekran coastal reks.* The following table shows the population density for the different reks of Mekran coast for September, October, November and December 1937:—

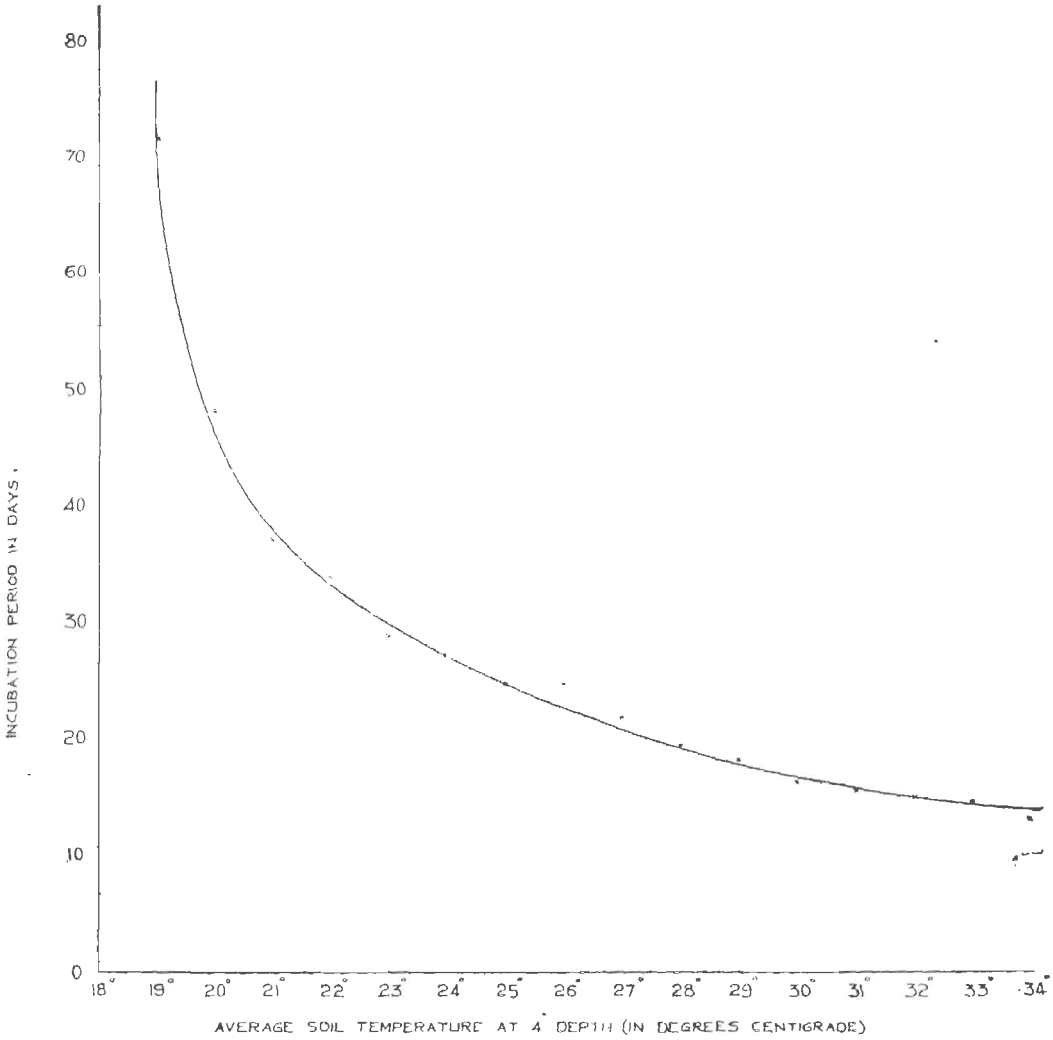
Areas	September	October	November	December
Ormara	51	2,780	1,117	40
Pasni	53	121	207	56
Gwadar	31	48	211	42

During September there was an increase of density as compared with August in all the reks. This was probably due to the entrance of immigrant locusts possibly from the desert breeding areas by way of the interior valleys of Mekran. As already stated, such migrants were actually seen during September in the Kolwa area by the locust survey staff. Most of those noticed in September had pink or mauve wing-bases. Some found at Pasni and Gwadar carried *green algae*, but as they had yellow wings they were possibly not immigrants. It is presumed that the September entrants were contemporaneous with the batches that reached the Lasbela area with the storms of the depression of 10 September in Sind. Easterly winds, which prevailed during the last week of September, had evidently much to do with the appearance of locusts by the beginning of October.

During October, migration apparently intensified. In the Ormara area especially, large numbers were found during the first fortnight, in the Rumra-Kalmat sector, the density being as high as 5,000 to 6,000 per sq. mile, and during a visit in the third week, the concentrations were found persisting in this area. The specimens collected had mostly light yellow wings with light mauve base and *green algal* patches were found on many of them.

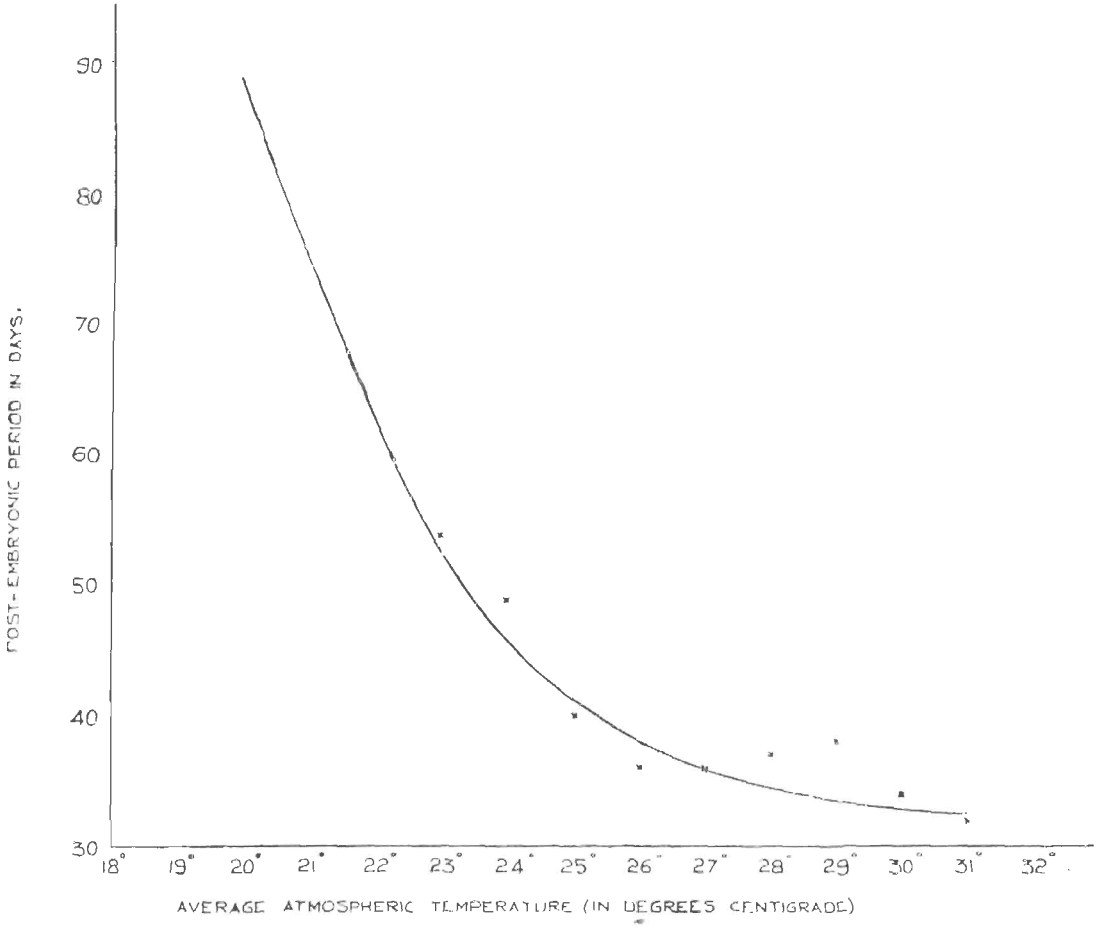
At Pasni and Gwadar, population density continued to be low till the third week of October, but during the last week, a sudden rise was noted at Pasni. From 28 October, quite a good number of locusts were noticed roundabout Pasni, the increase in numbers having attracted the notice

Text Figure 2]



GRAPH SHOWING THE RELATIONSHIP BETWEEN SOIL TEMPERATURE AT 4" DEPTH AND INCUBATION PERIOD.

Text Figure 3]



GRAPH SHOWING THE RELATIONSHIP BETWEEN ATMOSPHERIC TEMPERATURE AND POST-EMBRYONIC DEVELOPMENT

even of the Pasni townsmen. The specimens had hyaline or light yellow wings and carried red mites. A good many had light mauve or blue wing-base, and it was evident that a light incursion of locusts had occurred, obviously connected with the development of the *Gorich* or the northerly wind of Mekran, from the 24th onwards. The average density for the last week had been, owing to the incursion, as high as 327 per sq mile. Even at Gwadar, the presence of fair numbers on 31 October in the vicinity of the Gwadar hill attracted the notice of the local people, and in the course of surveys in the Gwadar-Pishukan area during the first week of November, the average density was found to be 280 per sq. mile. In November it was reported that there were rumours that small groups of locusts had recently appeared at Shehan Nigwar—in Iranian Mekran about 50 miles west of Gabd, which would indicate that the incursion noticed at Pasni and Gwadar had extended into Iran.

During the early half of October, specimens carrying *green algae* on their wings were noted both at Pasni and Gwadar. During the first part of November, the population density was fairly high on all the reks, but during the last week a decrease was noticeable. There was a further diminution in numbers during December everywhere.

Biometrical facies of the population

September 1937.—(92 specimens) 45S : 52T : 3G : : 80(6) : 20(7). The population probably represented the earliest migrants from the eastern areas.

October 1937.—(253 specimens) 57S:39T:4G: :78(6):22(7). (Probably forming the main body of the migrants from the Indian Desert area).

November 1937.—(203 specimens) 54S : 40T : 6G : : 71(6) : 29(7). (Probably representing the later batches from the desert).

The predominance of six-striped forms in the populations found in the autumn months is a rather striking feature.

Summary of the course of events in 1937

Fairly large numbers of locusts were found over-wintering in the Lasbela and Mekran coastal areas during the winter months, as also in the east Jaisalmer and west Bikaner areas of the Rajputana desert where late breeding had occurred in the autumn of 1936. No locusts were noticed in other parts of the desert region.

The winter rains proved a failure in the coastal areas of Mekran, but in the Lasbela area and in the hinterland of Mekran fairly normal rainfall occurred. There was good rainfall in the winter and spring months also in the Kachhi area and in Upper Baluchistan.

During spring, there was no breeding on any of the reks and the locust population gradually disappeared. In the interior, light breeding occurred in Kulanch, Kolwa and in the Rakhshan valley from Gar to Nagi-i-Kalat in late spring and early summer. In the Lasbela area, light breeding occurred in the Nakhetri-Khandewari section, but none in the Pohr-Hingol reks areas. In the Porali valley, however, concentrated breeding occurred on ten acres of cultivated land on the banks of the Porali at Goth Safarkhan near Sheh Lakhra during April, May and June, which apparently functioned as an 'outbreak centre', although hoppers were not numerous enough to form bands.

In the Kachhi area and in the Bolan valley, fairly prolonged and extensive breeding apparently occurred during April, May and June, and numerous hoppers and fairly large concentrations of fresh adults were noticeable. Owing to the development of high temperatures and low atmospheric humidity in the Kachhi-Bolan areas, the adults were found gradually disappearing, and it is presumed that they migrated into the Jaisalmer-Bikaner desert areas in May-June.

In the Mekran coastal areas, the appearance of migrants with pink or mauve wing-bases was first noticed in May at Pasni, Gwadar and Ambagh, and in June at Ormara and Chachro. It is considered probable that these had been derived partly from the breeding in the interior of Mekran and Lasbela, and partly from the Jask area and possibly also from the Oman region, where spring breeding is known to have occurred.

Owing to deficit rainfall in north Jaisalmer and west Bikaner in June-July, most of the migrants from the west gravitated into the eastern parts of the desert, *viz.*, in the areas of east Bikaner and west Jaipur where extensive egg-laying and multiplication occurred in July-August. There was good breeding also in the southern areas of the desert, *viz.* Thar-Mallani and south Jaisalmer.

A break in the monsoon covering nearly five weeks in August-September brought about conditions of drought, in the desert areas, leading to extensive displacements of adult locusts by migration. Observations made at this period have shown that, under conditions of drought, locusts availed themselves of the dynamics of thunderstorms for transporting themselves to centres of rainfall.

With the appearance of a depression from the Bay on 9 and 10 September, fairly good rainfall occurred in many parts of the desert, especially in the Thar area, and led to the development of a second monsoon brood. The thunderstorms associated with this depression had, moreover, the effect of sweeping off much of the adult population present in the desert westwards into Lasbela and Mekran.

During September, October and November, the appearance of numerous new generation adults with pink or mauve wing-bases was noted on the reks of Mekran and Lasbela, the biometrical facies of which strongly resembled that of the brood produced in the desert. A fairly large population was present in Thar during December and subsequently it was found that numerous adults as well as a few hoppers over-wintered in this area.

Some of the main characteristics of the 1937 season were (1) the absence of breeding on the coastal reks as contrasted with fairly high locust multiplication in the interior, (2) the occurrence of fairly intensive breeding in spring in Kachhi and Bolan, in association, with that of *Locusta migratoria,* and, also in the monsoon season, in the eastern desert areas and in Thar, along with *Locusta,* and (3) the occurrence of extensive migration of both species under similar climatic conditions.

Another characteristic of 1937 breeding was the dominance of forms with six-eyestripes and of *solitaria* ratios, with a slight increase of *gregaria* components.

STATEMENT VII—*Results of Locust Surveys—1937*

(The figures represent the average population per square mile for the whole month in the areas surveyed and 'H' indicates occurrence of breeding)

Seasons	Months	BALUCHISTAN										SIND-RAJPUTANA DESERT							
		MEKRAN						LASBELA											
		Gwadar Pishukan	Pasni Reks. (Int. Surveys)	Ormars	Panjgur	Kulanch Dasht	Kilwa	Hingol	Ambagh Reks. (Int. Surveys)	Bela Sheh-Lakhra	Hinidan	W. Sind & Kachhi & Bolan.	S. W. Punjab Bahawalpur.	Chachro (Int. surveys)	Thar. Mailani	E. Jaisalmer W. Bikaner.	Nokh (Int. Surveys)	E. Bikaner.	Sardar-Shahr.
Winter	December 1936	7	110	254	2	2	Nil	1	501	...	...	...	102	7	Nil	60	H 766		14
	January 1937	6	27	60	Nil	2	Nil	65	115	...	Nil	...	...	Nil	Nil	60	114	Nil	3
	February 1937	7	14	53	Nil	35	Nil	...	94	...	...	Nil	...	Nil	Nil	172	186	...	13
Spring	March 1937	Nil	11	Nil	13	12	H 30	H 161	15	...	...	6	Nil	Nil	Nil	32	8	Nil	Nil
	April 1937	Nil	5		8	18	1	...	Nil	H 120	Nil	...	7	Nol	Nil	Nil	Nil	...	Nil
	May 1937	5	12	12	11	H 3	124	27	15	H 1894	...	H 311	H 58	Nil	Nil	H 48	46	Nil	Nil
Summer	June 1937	22	46	14	H 14	6	Nil	...	69	H 1017	...	H 115	Nil	4	2	82	269	...	36
	July 1937	42	94	9	H 11	8	809	...	159	...	...	H 189	11	229	126	H 86	H 77	568	H 92
	August 1937	21	82	7	18	Nil	Nil	H 673	H 132	H 110	...	H 41	Nil	H 1554	H 683	H 247	H 142	H 6072	H 840
Autumn	September 1937	31	53	51	8	3	498	H 528	H 2061	Nil	68	..	H 49	H 5092	H 1151	H 778	1044	H 3002	H 1433
	October 1937	48	121	2780	H 2	25	Nil	H 2246	H 1913	Nil	H 480	44	H 42	H 1580	H 636	H 210	H 154	H 116	H 127
	November 1937	211	207	1117	Nil	30	28	130	H 981	Nil	H 112	H 220	Nil	H 2391	H 471	H 179	H 45	24	H 182

CHAPTER VII

THE PERIOD 1938-39

Year 1938

Weather Notes

Winter rainfall 1937-1938. Eight western disturbances appeared in August 1937, in the extreme north in Kashmir and North-west Frontier. Four were recorded in September, but only in the extreme north of India. Between October 1937 and June 1938, 57 disturbances were active in the regions of Iran, Baluchistan and North-west India.

Rainfall commenced in the Mekran areas about the middle of December. The last disturbance of December 1937 caused fairly widespread rainfall between the 29th and the 31st in Mekran, Lasbela and south Sind. One of the disturbances gave rise to fairly heavy precipitation in Mekran and Upper Baluchistan in mid-January 1938, and there was further rain in the interior at the end of the month. Heavy showers were recorded in parts of Mekran in February, first week, when Pasni received 1·36″ on the amorning of the 5th. Some further rainfall in the third week, after which there was little rain in Mekran, where winter rainfall was, on the whole, much below normal.

There was little rainfall in spring in Rajputana and, in Kachhi, little of winter rain except for one shower in January.

Monthly Rainfall data for Winter-Spring season, 1937-1938

Localities	Nov. 37	Dec. 37	Jan. 38	Feb. 38	March 38	April 38	May 38
Iran							
Jask	...	0·37	1·56	0·05	...	...	...
Charbar	...	4·20	3·87	...	...	...	...
East Arabia							
Muscat	...	1·05	...	...	...	...	...
Sharjah	...	1·33	1·21	0·19	...	...	...
Baluchsthan							
Pasni	...	0·87	1·57	1·27	...	...	...
Gwadar	...	0·38	2·09	1·36	...	0·01	...
Ormara	...	2·79	1·07	1·13	...	...	...
Turbat	...	...	0·39	0·90	...	0·53	...
Panjgur	...	0·28	0·69	0·45	...	0·15	...
Gandhawa	...	0·25	1·35	...	...	...	0·22
Bhag	...	0·25	0·60	...	...	...	0·70
Sibi	...	0·24	1·73	0·04	...	0·09	...
Bela	...	1·04	0·25	0·08	...	1·08	1·21
Quetta	0·06	0·14	5·06	1·33	1·17	1·12	...
Rajputana							
Sriganganagar	...	0·48	0·20	0·55	0·10	0·37	...
Bikaner	...	0·53	...	...	...	0·06	...
Jodhpur	...	0·90	...	...	...	...	...
Barmer	...	0·99	...	...	...	0·08	1·00
South West Punjab							
Dera Ghazi khan	...	...	0·72	...	...	0·15	...
Taunsa	...	0·02	0·57	0·40	0·37	0·73	...

It is thus seen that the winter rainfall was below average in most of the areas.

Monsoon rainfall 1938. The first symptoms of the monsoon were noticed in south Arabian Sea about 10 May. During the last week of the month, there was a depression off Konkan, under the influence of which Bela received 1·25 in., Barmer 1 in. and Fort Abbas 0·25 in. In the second week of June, a depression from the Bay carried rainfall into North-west India. Jodhpur received 2 in., Barmer 1·5 in. and Fort Abbas 2·5 in. In the latter half of June, another Bay depression caused further falls: Jodhpur 3·5 in., Multan 1·1 in. and Bela 1 in. The first fortnight of July was dry in the desert areas, but during the second the monsoon extended into Sind, Rajputana and Baluchistan under the influence of Bay depressions, Karachi recording 3·7 in., Badin 3·5 in., Ormara 1·1 in., Panjgur 3·3 in., Turbat 3·2 in. and Harnai Adm., At this time Chachro reported 3·68 in., Nokh 2·95 in. and Sardarshahr 0·96 in., but, on the whole, rainfall was much below average in Rajputana, especially in the north-eastern areas. The first part of August was also rather dry in North-west India, but a low pressure area occasioned light falls in Sind and Rajputana in the middle of the month: Jodhpur 1 in., Karachi 1 in. and Chachro 1·19 in. During the last week a trough of low pressure appeared over a region extending from Orissa to Gujarat, and heavy rainfall occurred in the western parts of this area—Cutch and Sind, where a depression formed. Karachi received 2 in., Badin 3·4 in., Chhor 3·1 in., Bikaner 2·6 in., Jodhpur 2·1 in., Barner 0·5 in. and Multan 1·7 in. September was practically rainless all over North-west India, from which the monsoon retreated by the 8th. Between the 12th and the 21st, there was a general rise of temperatures in the desert area (Bikaner and Jodhpur recorded maximum up to 107°F) as well as a marked fall of humidity. During the first week of October, under the influence of a cyclonic storm from the Bay of Bengal, which crossed the Peninsula into the Arabian Sea, northerly winds and unusually high temperatures prevailed in Sind and west Rajputana.

Monthly rainfall data for the monsoon period 1938

Localities	May	June	July	August	September
Rajputana Area					
Sriganganagar	...	6·54	3·53	1·05	0·15
Bikaner	...	0·71	1·35	2·60	...
Sardarshahr	...	0·92	1·39	0·59	0·22
Sadulpur	...	2·52	0·81	1·59	0·08
Churu	0·21	2·80	4·95	0·65	0·31
Nohar	0·10	0·85	0·44	1·65	0·30
Anupgarh	...	0·54	0·21	0·56	...
Nokh	...	2·07	4·68	0·72	...
Bap	..	...	2·38	1·32	...
Jaisalmer	...	1·46	0·41	2·24	...
Phalodi	...	0·30	1·70	0·51	...
Jodhpur	...	0·08	2·31	1·68	0·19
Barmer	1·00	2·25	1·07	0·58	...

Monthly Rainfall data for the Monsoon Period 1938—contd.

Localities	May	June	July	August	September
Sind Area					
Chachro . . .	0·52	0·81	6·35	2·14	..
Karachi . . .	0·13	0·34	3·78	2·75	..
Chhor . . .	..	..	0·92	3·06	..
Jacobabad . .	..	..	0·66	0·30	..
South Punjab					
Hissar . .	..	1·35	0·01	·036	0·31
Fort Abbas . .	0·26	2·68	2·72	..	..
Dera G. Khan . .	..	0·89	0·29	0·14	..
Taunsa . . .	..	1·61	0·14	0·27	..
Baluchistan Area					
Gandhawa . .	0·22	..	..	..	..
Bhag . . .	0·70	..	0·17	..	..
Bibi . . .	..	..	0·30	0·52	..
Bela . . .	1·21	1·10	4·38	0·91	..
Ambagh . . .	0·10	0·04	0·79	2·98	..
Ormara . . .	..	..	1·06	0·05	..
Pecni . . .	..	..	0·33	0·02	..
Panjgur . . .	..	..	3·20	..	..
Turbat . . .	..	..	2·16	..	..

The main features of the monsoon in the desert areas would appear to be a fairly early commencement in June, followed by moderate rainfall in July, deficient precipitation in August—especially in the north-eastern areas, and an early withdrawal of the mosoon in September.

Observations on locust distribution in 1938 (*vide* Statement VIII).

I. *Winter period* 1937-1938.

(a) *Sind-Rajputana areaH Southern desert areas.* A late second brood naving occurred in the Thar area, a fairly high population was noticed in December 1937 around Chachro and in the Thar-Mallani areas in general. At Chachro the average density for the month was about 1,170 per sq. mile, while that of the Thar-Mallani area was about 570. At Chachro several hoppers were met with even up to the last day of December. As a third-stage hopper was collected at Chachro as late as 6 February, 1938, and as several fresh adults with hyaline wings were found in January and February, it is obvious that some hoppers also had over-wintered at Chachro along with the adults.

On 18 December, 23 locust adults were met with around Chachro, indicating a density of over 2,000 per sq. mile, contrasted with 3 or 4 individuals found on the previous two days. This sudden rise of population was evidently connected with the occurance of light rainfall

accompanied by strong winds on the 17th. During the first week of December, fairly large concentrations of locusts were noted in the southern parts of Thar, but by the end of the month a decrease of population was noticeable in the area presumably by migration.

A fairly high population was, however, noticeable around Chachro as well as in Thar-Mallani area throughout January, February and March. The average density at Chachro for January and February was about 340 and 450 per sq. mile respectively, while for the Thar-Mallani area as a whole it was about 170 and 100 per sq. mile respectively. Observations indicated that at night and during cold spells locusts hid themselves at the base of bushes and were active only during sunny weather. Several specimens of dead locusts as well as their wings and limbs (presumably of victims of predatory birds) were found under the bushes. On 15 and 16 January, when a cold wave prevailed in the Sind-Rajputana desert (minimum 38·8°F. at Chachro and 30·5°F. at Nokh and Saradarshahr), few locusts were seen during surveys, but were observed again when the cold spell passed away.

Biometrical facies of the winter population in the Southern areas

December 1937. (15 *specimens*) 67*S*:20*T*:13*G*: :73(6):27(7).

January 1938. (21 *specimens*) 76*S*:24*T*:*OG*: :72(6):28(7).

February 1938. (43 *specimens*) 70*S*:30*T*:*OG*: :86(6):14(7).

Some of the marked locusts were recovered during the winter months near the place of liberation at Chachro, and in one case an individual set free in the latter part of January was recollected on 6 March at a distance of half a mile, indicating that during the cold weather migration is infrequent.

Northern desert areas. Unlike the previous year very few locusts were seen at Nokh during the winter months. Only four individuals were met with during December 1937, two during January, 1938 and three during February. None were seen in east Jaisalmer and west Bikaner with the exception of five individuals observed on 26 February at Mohangarh and one found at Pugal on the 28th. At Sardarshahr also few were found in the immediate vicinity of the outpost, but in villages within a radius of about ten miles a fairly high population was found during the cold weather. The average density was noted to be about 200, 37 and 51 per sq. mile respectively for December, January, and February. There was thus light over-wintering at Sardarshahr, but by March all locusts had disappeared.

Biometrical facies for the northern areas

December 1937, January and February 1938

(27 specimens) 44S:52T:4G: :59(6):42(7).—A few collected from Sardarshahr in February had colonies of green algae on their wings.

(b) *Lasbela area.* Except for about half an inch of rain at the end of December, 1937 and a further half inch at the end of January, 1938, there was little winter rainfall at Ambagh. Locusts were found in fair number at Ambagh throughout winter, though a considerable fluctuation in density was noticed, due partly to migration and partly to the effect of cold spells. A great many had pink or mauve wing-bases and several were infested with *Tyroglyphid mites.* The average density at Ambagh during December 1937 was about 300 per sq. mile, and for January and February 1938 about 480 and 345 respectively. In January and February, several wings were found under bushes, as also a few dead locusts, indicating the occurrence of numerous casualties during winter.

During January, certain locusts marked and released during the second fortnight of September, and in the course of October, November and December 1937 were recovered on different dates, indicating that a certain proportion of the population had not moved out of the Ambagh area during autumn and winter. On the other hand, several cases of high flights were observed in the course of surveys during January and February, which would show that the spirit of migration was by no means lacking.

During December 1937 and again in February 1938, the Hingol areas were examined and a fairly high population (the average density for December being about 150 and for February, about 124) was noted, especially in the Nakhetri-Khandewari area. Many had pink or mauve wing-bases, and some had *Tyroglyphid* infestation. In February, one of the specimens showed froth on the ovipositor indicating that egg-laying was then in progress.

Biometrical index of the population

December 1937. (53 *specimens*) 58*S*:35*T*:7*G*: :79(6):21(7).

January 1938. (46 *specimens*) 46*S*:52*T*:2*G*: :74(6):26(7).

February 1938. (58 *specimens*) 54*S*:41*T*:5*G*: :72(6):28(7).

22 per cent. of the locusts captured in January and 45 per cent. of those of February, carried *green algae* on their wings. The colonies were in different stages of growth and varied greatly in numbers. It is presumed that their growth had been stimulated by the winter showers received in December and January.

(c) *Mekran area.* (1) *Mekran interior.* In December 1937, no locusts were located in the interior except for one found at Turbat on the 20th. In January, only one individual—a male with bluish wing-base was collected on the 12th between Goshanak and Awaran in Kolwa. In Kulanch, however, a few locusts were observed on the 21st and 22nd between Nokbur and Sardasht, evidently stragglers from the coastal areas. In February, only three specimens were found in the interior. One was a male with light pink base found at Turbat on the 14th. It carried several colonies of green algae and was, thus, a migrant from the coastal areas. The other two were a male and a female collected on 26 February between Rotak and Thana Daragh in the Panjgur area. Both of them were migrants as they had mauve wing bases, and the male carried a few green algae. In Kulanch and Dasht, however, large numbers of locusts were met with, mostly in the Kulanch area, few being found in the Dasht valley in view of the lower rainfall. The average density in the Kulanch-Dasht area was about 227 per sq. mile, over 35 per cent. of the locusts being found to have green algae on the wings.

(2) *Mekran coastal areas.* The following table shows the average density noted in the different reks during winter.

Areas	December	January	February
Ormara	40	860	1,210
Pasni	56	68	89
Gwadar	42	34	55

As Ormara received about 5 in. of rainfall in winter as against less than 4 in. recorded at Pasni and Gwador, conditions were apparently better there for breeding. Larger concentrations of locusts were observed in the Ormara areas than elsewhere, and even in these, larger numbers were noticed on the Had-Chad-Manijikaur reks than on the Rumra-Kalmat reks, presumably due to difference in rainfall. Locusts were mostly mature during January; and in February several instances of pairing were noticed, and as hoppers were found in March, oviposition had probably commenced in February. Several cases of high flights were noticed during January at Pasni and elsewhere in general.

Biometrical index of the population

(1) *Mekran interior.*

December, January and February—1937-1938:

(45 specimens) 60*S*:38*T*:2*G*: :65(6):35(7).

(2) *Mekran coastal reks.*

December 1937.—(39 specimens) 56*S*:44*T*:0*G*: :72(6):28(7).

January 1938.—(106 specimens) 56*S*:38*T*:6*G*: :67(6):33(7).

February 1938.—(160 specimens) 59*S*:36*T*:5*G*: :58(6):42(7).

In respect of the population found on the coastal reks, about 12 per cent. of the collections of January and about 20 per cent. of those of February carried green algae. *Tyroglyphid* mites were present in four per cent. of the locusts collected.

II. *Spring period* 1938

(a) *Sind-Rajputana area*: (1) *Southern desert areas.* As already mentioned, there was considerable over-wintering in the Thar-Mallani area, during the cold-weather. During March, few locusts were met with except at Chachro, where the average population for the month was as high as 226 per sq. mile. By the end of the month, however, the population had considerably diminished, and during April only eight individuals were found at Chachro, indicating an average density of 21 per sq mile, whereas during May no locust was noticed. The factors that apparently were responsible for the disappearance of locusts in the Thar-Mallani area were meteorological in character, as may be seen from the data given below:—

Localities	Highest Maximum Temperature during month	Relative Humidity (Mean)	
		8 a.m.	5 p.m.
	(Degrees Fahrenheit)	(Percent)	
January 1938			
Chhor	87	59	38
Chachro	86·5	62	25
Barmer	82	51	24
February 1938			
Chhor	101	59	38
Chachro	98	62	25
Barmer	94	47	20

Localities	Highest Maximum Temperature during month	Relative Humidity (Mean)	
		8 a. m.	5 p. m.
	(Degrees Fahrenheit)	(Percent)	
March 1938			
Chhor	105	68	27
Chachro	104	72	31
Barmer	101	50	22
April 1938			
Chhor	114	55	27
Chachro	113·5	64	22
Barmer	118	49	25
May 1938			
Chhor	116	..	..
Chachro	116·5	54	50
Barmer	116	58	28

It may be noticed that in March there was a sudden rise in the maximum temperature, accompanied by the occurrence of low air humidity in the afternoons, and these conditions were much accentuated in April. In May temperatures were high, but there was a rise in humidity on account of the setting in of the south-west winds from the coast.

The disappearance of locusts from the Chachro area is presumed to have been by emigration, but there is no definite evidence as to the direction taken by the migrating individuals. In March at least 33 per cent. of the locusts collected at Chachro carried green algae on their wings. As most of the locusts found on the Ambagh reks during April and May had mauve or pink wing-bases and also had green algae and as, moreover, a few locusts found on the Baran River bed in mid-April had pink wing-bases and one of them carried green algae, it is considered probable that the migration had been in a west-ward direction.

The population found at Chachro in March had the index: (31 specimens) 71*S*:29*T*:*OG*: :94(6):6(7).

(2) *Northern desert areas.* Except for a single individual found on 2 March at Harpalsar near Sardarshahr, no locusts were noticed anywhere.

(b) *Kachhi—Upper Baluchistan areas.* During a visit paid to the Kachhi-Bolan-Harnai areas in the latter part of March, very few locusts were met with. One was found at Gadi near Bhag on the 22nd and one female—with soil sticking to its ovipositor—in a wheat field at Kirta on the 26th. The latter had evidently laid eggs recently. Several adults of *Locusta migratoria* were also found at many of the places examined. In April, a male with bright yellow wings was collected at Dalbandin in Chagai district on 4 April. As it carried a few colonies of algae, it is presumed to have been a migrant from the coastal areas of Lasbela or

Mekran. Two more specimens with bright yellow wings were found on 28 April at Gandhawa, of which one had traces of green algae on its wings. In May, good numbers of locusts were observed in Kachhi and in the Bolan valley. At Kirta in the Bolan valley, 60 locusts of a recently fledged brood were noted on the 15th, along with 4 V-instar hoppers; on the 16th, 25 young adults were found in harvested wheat fields between Kirta and Peshi, and on the 17th four adults and 42 hoppers of different stages were collected at Mashkhaf in *jowar* fields. The adult locusts found at Mashkhaf were evidently of the old brood as the wings were bright yellow and carried a few green algae. It might be mentioned that at this time, large numbers of adults and hoppers of *Locusta migratoria* ph. *solitaria* were noted in cultivated fields and among grasses in the Bolan and Harnai valleys.

The biometrical index of a collection made in May in the Bolan valley was: (32 specimens) *56S:41T:3G: :74(6):26(7)*.

Whereas, in 1937, extensive multiplication was noticed in April—May in Kachhi, there was no breeding in 1938, there having been little rainfall after January 1938. In the Bolan valley, light breeding was noticed in April-May in the irrigated wheat fields in 1938, whereas in the previous spring much heavier breeding had occurred.

(c) *Lasbela area.* During March, a fairly high population was noticed on the Ambagh Reks, the average density being about 198 per sq. mile. Most of the locusts had yellow wings, with pink or mauve tinge at the base, and about 50 per cent. had colonies of green algae on the wings. Outside the reks, there were few locusts noticeable in the Lasbela area, except near Nakhetri where about 50 locusts (about 750 per sq. mile) were found as well as 76 green hoppers (1 to IV stage) mostly on '*Dranna*' (*Crotalaria burhia*). The locusts found concentrated in this area were all of the over-wintered brood and had yellow or bright yellow wings. About 50 per cent. carried colonies of *Tyroglyphid* mites on the thorax and wings.

During April, the population had greatly decreased, the density being only about 71 per square mile at Ambagh, and no locusts were found in the interior at Sheh Lakhra or the Porali valley as contrasted with the previous year. Most of the locusts had pink or mauve tinge on the wings, being apparently migrants and over 77 per cent. carried colonies of green algae.

In May, the density on the Ambagh reks was about 100 per sq. mile, the locusts noticed being similar in character to those of April. They were all of the old brood and about 80 per cent. had green algae. In the Hingol area locusts were observable only in the Pohr-Nakhetri area, where a few adults with hyaline or light yellow wings—evidently a recent brood—and a few hoppers (II to V stage) were collected, as well as two adults of the old brood.

Biometrical index of the population. March-April-May 1938. (98 specimens) *53S:44T:3G: :69(6):31(7)*.

(d) *Mekran area*

(1) *Mekran interior: Kulanch—Dasht area.* In March, good numbers of locusts were met with in most places. The average density was about 133 per sq. mile for the whole area. Good numbers of hoppers were noticed all over Kulanch, especially at Khandasole, Ban, Chibvari, Nokbur and Bonap, mostly on '*Kapocham*' (*Chrozophora*) *and* '*Marrand*' (*Heliotropium undulatum*). They were mostly green in colour except a

few which had brown or black patches. The majority of the hoppers found in March belonged to I, II and III instars, but one IV and two V stage specimens were also noted; presumably in the latter cases oviposition had occurred by the end of January. In the Dasht valley, on the other hand, hoppers were seen at only one locality (between Goharag and Pittu) on the 22nd and in small numbers.

In April, somewhat larger numbers of hoppers were noticed in the Dasht area, (Hassadi, Suntsar and Puttan), as also a few adult locusts, while in Kulanch good numbers were found in many places, especially round about Kappar, Ban and Nokbur. The first adult of the new generation was collected on 14 April at Kandasole, and a few more adults later on at other places. The average density for April was 79 per sq. mile.

In May, three hoppers were noted at Kappar on the 16th, three more at Suntsar on the 22nd and one at Nokbur on the 29th. No hoppers were found elsewhere in the area, but adult locusts (mostly of a recently developed brood) were noticed in fair numbers in many places. The average density for May was about 134 per sq. mile.

Kolwa Area. In March, two mature locusts were met with on the 11th at Chambar-Kalat and 16 adults in a cultivated field at Rodkan on the 19th, most of which had yellow wings, and some carried a few algae colonies—being presumably migrants from the coast. In April, however, no locusts were met with anywhere in Kolwa, except for a single hopper found in a cultivated field at Chambar-Kalat on the 20th. Neither hoppers nor adults were seen in Kolwa during May.

Kech and Panjgur. No locusts were located anywhere during the spring months in the Kech-Buleda areas.

In the Panjgur-Nagikalat areas, no locusts were met with in March-April, but in May a small number of adults and about 10 hoppers (I to IV instars) were found in the Sohrap-Gar area (6-8/v), and in the Nagikalat valley (21-28/v) 3 adults of the old brood (one of which carried traces of green algae), as well as two hoppers (I and III instars) were collected. This would indicate that light breeding had occurred in the Panjgur area during April-May.

Biometrical Index of the Population in the Interior

March 1938: (*Kulanch-Dasht-Kolwa*) (124 specimens) *63S*: *34T*:*3G*: :*57*(*6*):*43*(*7*).

April 1938: (*Kulanch-Dasht*) (19 specimens) *58S*:*42T*:*0G*: :*89*(*6*): *11*(*7*).

May 1938: (*Kulanch-Dasht-Panjgur*) (48 specimens) *67S*:*33T*: *0G*: :*63*(*6*):*37*(*7*).

In the case of the population found in May in the Kulanch-Dasht area, nearly 60 per cent. were of the new brood, the wings being either hyaline or light yellow.

(2) *Mekran Coastal Reks.* As already stated, the coastal areas received a moderate amount of rainfall during the winter months, and as a result locusts were fairly numerous on most of the rek areas during February and March. They were generally in a mature condition and pairing was noticed. At Pasni, the first hopper of the season was noticed on 5 March on a Marrand plant,

and was said to have been dark brown in colour, but those collected later were of the normal green type. In the Ormara area, good numbers of hoppers were found on all the different reks, but at Gwadar, none was met with till April and the breeding was, on the whole, scanty. Hoppers were numerous in April both at Pasni and Ormara, and the first adult of the new generation was observed at Pasni on 11 April and in Ormara on the 18th. In the Gwadar area, new generation adults began to appear by the 25th. After middle of May, hoppers were but rarely met with on any of the reks. At Pasni, however, they were found in small numbers in the special areas, even after their disappearance on the general reks.

Apparently there was a good deal of fluctuation of population in the various reks between February and May, as may be seen from the averages tabulated below:—

Areas	February	March	April	May
Ormara	1,210	311	149	115
Pasni	89	160	276	198
Gwadar	55	165	45	24

The relative density in the different areas in February and March would indicate a gradual transference of locusts from eastern to western areas during March and to a less extent in April. In April and May, the new brood was found forming a considerable part of the rek population, but from the circumstance that a decrease, instead of an increase, in density was noticeable in May, a partial emigration was at the same time in progress.

While among the collections made in March, 25 per cent. carried green algae and 11 per cent. *Tyroglyphid* mites, and in April, 20 per cent. had green algae and 33 per cent. the *Tyroglyphid*, barely 4 per cent. of the May collections carried green algae and none had any *Tyroglyphid*. This would show that the population in May was mainly composed of a new brood, which had not yet become infected.

Biometrical index of the population

Mekran Coastal Reks: March 1938: (146 *specimens*) *56S: 41T:3G : :65(6):35(7).*

April 1938: (74 specimens) *57S:39T:4G: :69(6):31(7).*

May 1938: (81 specimens) *57S:36T:7G: :72(6):28(7).*

III. *Summer Period*—1938

(a) *The Mekran area.* (1) *Mekran interior: Kulanch-Dasht area.* Nine locusts were found among cultivation at Kappar on 9 and 10 June, and subsequently only one individual on the 13th at Kappar and another on the 25th at Nokbur. Two locusts were also noticed on the 19th at Suntsar. They had mostly hayline or light yellow wings, being probably locally bred ones. In July, only two locusts were seen, one at Kappar on the 10th and another on the 15th near Kandasole, and none in August.

Kech-Panjgur areas. In the Kech valley, good rainfall occurred in the last week of July, Turbat recording over two inches in all, but no locusts were seen except for a female captured on 5 August on the bed of the Kej Kaur near Turbat. In the Panjgur area, the light breeding noted in May continued in June. Several fresh adults as well as a few hoppers, were found on the Sohrap Kaur on 15 June. More hoppers were located at Gar and Sar-i-Parom between the 16th and the 19th on *Chrozophora* in Jowar-melon fields, as also 6 adults—mostly of the old brood, with yellow wings and also green algae in the case of two.

Between the 7th and the 10th July, 16 locusts (with hyaline wings) were found at Sohrap on the 7th, and a few hoppers and 8 adults (of which 2 or 3 had yellow wings, with green algae on one) at Gar and Sar-i-Parom. A few locusts were also found at Zandidaz near Panjgur. During the last week of July, heavy rainfall occurred in the Panjgur valley, Panjgur recording a total of 3·26 in. Contrary to expectation, no further breeding was observed in this area, but several adult locusts (mostly with yellow wings and pink or mauve wing-bases) were found in the Nag-i-Kalat valley between 3 and 5 August. A female with yellow wings was found near Dash-i-Shah-baz on 23 August.

Kolwa area. In Kolwa, eight locusts were met with on the Sigak Dhak (Plain) and one more in Sigak fields on 8 June. They were apparently mature and had yellow wings with mauve colour at the base and three of them had green algae. None was found in the other parts of Kolwa. The small concentration noticed on the 8th at Sigak is probably to be associated with the prevalence of the hot *Gorich* wind from the north on the 7th and the 8th in Kolwa, and was apparently composed of the old brood found in the Panjgur area in late spring

Between 20 and 26 July, heavy showers accompanied by north-east winds were experienced all over Kolwa. One female locust with hyaline wings was found in a field at Sigak on the 25th and another—a male with light mauve at wing-base—was collected on the 26th between Sigak and Hoshab. Kolwa was next visited only in September and as, at that time, several hoppers and young adults were met at various places, it is obvious that the heavy showers of July had stimulated a certain amount of breeding.

Biometrical index of the population

June 1938. (*Kulanch-Kolwa-Panjgur*) (30 specimens) 70*S*:30*T*:0*G* : :50(6):50(7).

July 1938. (*Panjgur*) (8 specimens) 75*S*:25*T*:0*G*::71(6):29(7).

August 1938. (*Panjgur*) (6 specimens) 82*S*:18*T*:0*G*: :33(6):67(7).

(2) *Mekran Coastal reks.* The following table shows the relative population in the various reks in summer.

Areas	June	July	August
Ormara	43	38	15
Pasni	59	52	13
Gwadar	11	7	3

Whereas locusts were noticed in the Pasni and Ormara areas throughout June, at Gwadar no locusts were seen till the later part of the month. At Pasni, specimens with pink or mauve wing-bases were found to appear on the reks only from 8 June, but by the second half June they were commonly met with on all the reks. Some of them had light yellow wings and others yellow wings with green algae in some cases. Most of these were presumably migrants from outside consisting partly of the new generation and partly of the over-wintered brood.

In July, the population was, on the whole, thinner, but most of them had pink or mauve wing-bases, though three specimens with green algae were noted. In August, the density was lower and the wings were yellow mostly without any tinge of mauve.

At Pasni, a few hoppers were noted in June and July, but were met with only in the special areas such as Gandhako and Shahi-gurband, where prolonged breeding had been noted in years of good rainfall like 1933 and 1935.

Biometrical index: *Mekran Coastal Reks*

June 1938. (49 specimens) 82*S*:16*T*:2*G*::47(6):53(7).

July-August 1938 (47 specimens) 71*S*:24*T*:5*G*::49(6):51(7-8).

In this connection, it may be mentioned that a single specimen of a form with 8 eye-stripes was collected on the Pasni reks at Gurrani on 25 July 1938. It was a female with *solitaria* ratio (E/F 1·99), light yellow wings and a light mauve wing-base—evidently a migrant.

A higher proportion of *solitaria* and 7-striped forms than in the case of the spring population is recognisable in the summer collections.

(b) *The Lasbela area*. The influence of the monsoon was felt in the Lasbela area as early as the last week of May, when Ambagh recorded a shower (0·16 in.) on the 25th and Bela 1·21 in. of rain. In June, Bela had 1·10 in., but at Ambagh there was only a light drizzle (0·04 in.). In July, a sharp shower measuring 0:79 in. was received on the 22nd at Ambagh, but in the interior there was heavy rain (Bela 4·38 in.). In August, under the influence of two depressions that reached the Sonmiani coast from the direction of Karachi, 1·16 in. was recorded at Ambagh on the 16th and 17th, and 1·81 in. on the 28th and the 29th. Falls were presumably heavier at Gadani—midway between Ambagh and Karachi.

In June, fair numbers of locusts were met with on the reks during the first fortnight, but very few during the second. Many of them had pink or mauve bases and some carried green algae and were probably migrants from the west. In July, only five were located and in August, only four. Most of them resembled the individuals found in June and two of the July finds had green algae.

In the interior, only one locust—a male with mauve base—was met with near Chandragup in the Hingol area on 12 July. A V-stage hopper was found on the hedge of a field on 19 August in the Gajri Kaur area near Bela, which would indicate that stray breeding had followed the heavy rains of July in the Bela area.

The average density for the Ambagh rek areas for June, July and August were 21, 8 and 6 per sq. mile respectively.

The biometrical index.—(14 specimens) 72*S*:21*T*:7*G*: :50(6):50(7).

In this connection, it is interesting to note that a female locust was collected on the Ambagh rek on 13 July, which possessed typical *gregaria* ratios E/F 2·24, P/C 1·62 and H/C 1;125—and bright pink wing-base,

and 6-striped eyes. The appearance of a typical *gregaria* form among a predominantly *solitaria* population is rather remarkable, and might indicate its origin in a stray outbreak centre that had developed somewhere in late spring, though it is also possible that the *gregaria* characters might have been the result of active life led in the hopper stage.

Karachi area. One locusts specimen was sighted on 14 June on the bed of the Malir river, and another with bluish wing-base was collected on the bed of the Baran river on 13 July. No others were met with.

(c) *Upper Baluchistan—Kachhi—Dera Ghazikhan.* The Dera Ghazikhan area was visited in June first week, and a single locust was found. There was apparently no spring breeding. None was seen when visited next on 25 August.

Kachhi area was examined in June and again in July, but the desert locust was not met with, though fairly good numbers of adults and a few hoppers of the migratory locust were noticed in July.

Various parts of Upper Baluchistan, *viz.* the Bolan and the Harnai valleys, Loralai, Barkhan, Kohlu, Quetta and Spezand, were examined in June, and again in August. In June, three desert locusts were located near Kirta in Bolan valley on 14 and 15 June, and one more on the 16th at Harnai. A few hoppers were also collected at Kirta. No more were found in June, and none in August, but the Migratory locust (*Locusta migratoria* ph. *solitaria*) was noted in June in the adult and hopper stages in very large numbers at Kirta and Harnai and in fair numbers at various places in Upper Baluchistan. It was also noticed in small numbers in the adults and hopper stages at the end of August at Barkhan and Kohlu.

(d) *Sind-Rajputana area.* 1. *Southern Desert areas: June* 1938. Chachro recorded 0·47 in. on 25 May and 0·81 in. during June (with 0·44 in. on 10th), and Barmer about 1 in. on 31 May and 2·25 in. in June (with 1·53 in. on the 10th), so that the Mallani area had, on the whole, very early and fairly good rainfall in May-June. No locusts were noticed anywhere in June at Chachro, but at Barmer a I-stage hopper was found on 22 June, as also an adult with bright yellow wings. On the 25th five more I-stage hoppers were collected at Barmer, and on the 27th a locust with light yellow wings at Sanawra in Mallani. It is presumed that the winds prevailing at the time of the heavy falls of 31 May and 10 June had carried locusts into the Barmer area and brought about light breeding.

July-August, 1938. In July, Chachro had a spurt of heavy rainfall totalling 4·35 in., between the 19th and the 30th. Whereas none had been seen at Chachro since April, one locust was found on the 22nd associated with a heavy fall of 3·68 in. Subsequently another was collected on the 27th and two more on the 28th. One adult of *Locusta migratoria* was caught on the 30th. It is very likely that the appearance of these individuals was due to the agency of winds connected with rain-storms. In August the total monthly fall was 2·14 in. received between 16 and 31 August (with 0·84 in. on the 16th), and 21 locusts were noted during the second fortnight, as against only four during the first. Hoppers of the I-instar were first noticed on 13 August at Chachro, indicating that oviposition had occurred immediately after the heavy rainfall in the last week of July. Small numbers of hoppers were met with during the rest of the month.

On the other hand, Barmer received much less precipitation than Chachro during July and August. In July, Barmer had a total fall of

1·07 in. with a maximum of 0·76 in. on the 21st; and in August, there was a total of 0·53 in. During surveys made around Barmer, only light breeding and a thin locust population were noticed. In August, during a tour in Mallani and Thar, a few adults of both the desert and the migratory locusts were met with. One of the desert locusts collected on 13 August at Bhakasar in south Mallani had transparent wings and was apparently the first adult of the new brood of this area. At Chachro an adult with hyaline wings was found on 29 August.

The average density for Chachro for June, July and August was nil, 8 and 46 per sq. mile respectively. The biometrical index for the Thar-Mallani area was: *June, July and August* 1938: (12 specimens) 75S: *25T*: *0G*: :*42(6)*:*53(7)*.

2. *Northern Desert areas.—June* 1938. There was no rainfall in May at Nokh and Sardarshahr. During the second week of June, Nokh had 1·40 in. (1·27 in. on the 12th), and Sardarshahr 0·79 in. (with 0·49 in. on the 15th). During the last week, Nokh had 0·67 in. (with 0·61 in. on the 24th), but Sardarshahr had only very light showers. There was, however, fairly good rainfall in June in many parts of east and north Bikaner. No locusts were found at Nokh, but at Sardarshahr, where none had been seen since March, two were observed on the 14th and the 15th following a severe dust-storm on the 13th, and on the 14th, a specimen of *Patanga*, was also collected, A desert locust was captured on the 14th at Raman (Patiala State). One was noticed at light at Palana near Surpura on the 26th, and another (a female with froth on ovipositor) on the 28th at Sadulpur. All the June specimens had bright yellow wings and were evidently of the old brood, and probably represented the earliest migrants of the season.

July 1938. Nokh had heavy rainfall between the 23rd and the 27th (2·95 in. on the 23rd and 1·16 in. on the 25th) and Sardarshahr had a total fall of 1·36 in. in July (with the main fall of 0·96 on the 23rd).

At Nokh, no locusts were seen, with the exception of two found on the 2nd, till the period of heavy rain during the last week. On the 23rd, there was a heavy downpour in the small hours of the morning (2·95 in.) and in the afternoon drizzles occurred (0·18 in.) accompanied by a heavy dust-storm from the south. On the 24th, 11 specimens of *Schistocerca* and 3 of *Locusta* were collected during surveys in bright sun-shine. On that day, light rainfall (0·29 in.) was received at about 5 P.M., and after 9 P.M. there was a heavy dust-storm accompanied by 0·89 in. of rain. On the 25th, in sun-shine interrupted by clouds, seven of *Schistocerca* and four of *Locusta* were collected. At 6 P.M. that evening, a severe dust-storm occurred, and the next day only single examples, one each of the desert and migratory locusts, were found, and few were seen after that date. Most of the specimens collected on the 24th and the 25th had deep yellow wings, and three of the lot found on the 24th carried *green algae* indicating their probable origin from the coastal areas of Baluchistan. Attention is drawn in this case among others to the note "The Influence of Dust-storms on the Migrations of the Desert Locust' [Bhatia 1939] to illustrate how migration is directly influenced by dust-storms. There is little doubt that individuals of both *Schistocerca* and *Locusta* had been carried into the Nokh area by the dynamics of rain-storms, and the circumstance that some hoppers were found at Nokh about a month later would indicate that eggs had been laid at the end of July in the wake of the rains. At Sardarshahr no locusts were located in July but on 8 July, six were observed between Sonpalsar and Malkisar, and on the 20th, three between Surpura and

Lalamdesar to the south of Bikaner. All these had bright yellow wings and one of those captured on the 20th carried green algae.

August 1938. At Nokh and Sardarshahr, there was little rainfall except in the last week, when total falls of 0·72 in. and 0·57 in. respectively were recorded. There was, on the whole, very little rainfall in the northern areas of the desert during August. At Sardarshahr, no locusts were noted except for a single adult of the migratory locust captured on 14th August. At Nokh also, none was seen in the immediate vicinity, but within a radius of five miles, small numbers of locusts and hoppers were found during the second fortnight. In west Bikaner a few locusts were seen at Girasar and Srikolayatji, and in east Jaisalmer, two were found on the 5th at Lathi. In north Bikaner, a fairly good number was noted at Sri Ganganagar on the 16th, including a large proportion of newly fledged adults. A few hoppers were also noticed, indicating that light breeding had occurred in the Canal colonies. At Hanumangarh and Phephana, small numbers of hoppers and a few adults were seen in the middle of August, and a locust with light yellow wings was noted at Raman (Patiala State) on the 20th. *Locusta migratoria* was seen in fair numbers in many of the above areas.

Biometrical Index: Northern Desert areas: June-July 1938. (24 specimens) *96S:4T:0G: :83(6):17(7).*

August 1938. (24 specimens) *79S:21T:0G: :45(6):54(7).*

Whereas the locusts collected in June-July were of the old brood—presumably derived from the western areas, the population in August included a good proportion of the new generation, with a large proportion of 7-striped forms.

Summer migration in 1938.

Unlike previous years, there were only feeble indications of its occurrence during the summer of 1938. Whereas in other years, the entry of fair numbers of migrants was observable even by the end of May at Nokh and Chachro, the first entrants were this year noticed at Nokh only on 2nd July and at Chachro only on the 22nd. In the north, however, they would seem to have appeared earlier, as evidenced by the collection of a locust on 6th June at Dera Ghazikhan and another as far north as Raman in Patiala State on 14th June. Two specimens were moreover brought into Sardarshahr from the north-east by dust-storms on the 14th, and several were found at different places in eastern and southern Bikaner at the end of June. The occurrence in July at Nokh and Surpura of yellow-winged individuals with green algae on their wings would indicate that these locusts were probably derived from the coastal areas of Mekran and Lasbela where they were present in good numbers in April, May and June.

The winter rainfall in the Mekran areas was below average and the spring breeding on the reks was very moderate. Even in the interior of Mekran, only light breeding occurred, except in Kulanch. The rainfall data for the East Arabian and Iranian coastal areas indicate that the precipitation was even lower than in British Mekran except at Charbar, and it is therefore unlikely that any considerable breeding had taken place in spring in these areas except perhaps in the Charbar region. A few locusts with pink or mauve wing-bases found in the Panjgur and Kolwa areas in June and July were probably partly derived from these areas.

On the Mekran and Lasbela reks, the entry of migrants from outside was first noticed on 11 June at Pasni, and more or less about that time on the other areas. This was apparently connected with the development of the *Gorich* wind on the 7th and 8th, and subsequently on the

12th and 13th, in the Kolwa and Panjgur areas. As some of the migrants carried green algae, it is surmised that they were derived in great part from the interior valleys of Mekran, where such over-wintered forms were known to have been present in addition to the newly fledged ones. Immigration evidently continued up to the middle of July. As the population on the coast was, all the same, gradually diminishing, emigration towards the east was also obviously taking place simultaneously.

The following data extracted from the Monthly Weather Data for 1938 would indicate the conditions under which migration had occurred at the beginning of summer.

Monthly Meteorological Data for April—July 1938 for the Western Areas

Localities	Maximum Temperature			Humidity		Dominant wind direction		Cloud Amount	Rain
	Mean Max :	Highest Max :	Date of occurrence	8 A.M.	5 P.M.	8 A.M.	5 P.M.		
April 1938	Degrees Fahrenheit			Percent					Inches
Nokkundi	95·2	105	21,30-iv	2[illegible]	16	E ; SE	NW; N; S	1·4	0·19
Dalbandin	91·8	101	21,22,30	34	21	Cm ; SW	Cm; SW;W	1·7	0·40
Panjgur	90·2	99	29-iv	78	47	NE; E; Cm	SW; W; NW	1·0	0·15
Pasni	90·8	104	29-iv	77	65	W; NW; Cm	SW; W	2·1	nil
Sibi	100·6	112	30-iv	28	..	Cm, NE; E	—	2·0	0·09
May 1938									
Nokkundi	106·7	114	23-v	18	14	N;NW,SE;E	N; NW	0·8	nil
Dalbandin	104·5	111	22-v	33	22	Cm; NE; E	Cm; N; S	0·9	nil
Panigur	101·1	108	22-v	45	24	NE; N; SW	N; SW; NW	0·2	nil
Pasni	93·9	112	10-v	75	66	W; NW	SW; W; S	3·8	nil
Sibi	114·3	122	12-v	24	..	SW; NW	..	0·4	nil
June 1938									
Nokkundi	108·4	115	6-vi	18	11	N; SE; NW	N; NW	0·4	nil
Dalbandin	107·4	112	5,6-vi	..	..	Cm; SW; W	Cm; SW; W	0·8	nil
Panigur	102·0	106	6,7-vi	50	24	Cm; NW	N; NW	1·8	nil
Pasni	93·7	107	14-vi	77	74	W; NW	SW; W	4·5	nil
Sibi	113·2	119	8-vi	38	.	SW Cm S	.	1·1	nil
July 1938									
Nokkun	108·1	120	21-vii	31	17	N; NW; W	NW; N	1·4	nil
Dalbandin	106·7	117	21-vii	32	20	Cm; SW; W	Cm; SW; W	1·6	0·79
Panjgur	98·6	107	18,20-vii	57	45	N; W; Cm	N; NW; SW	1·6	3·26
Pasni	90·0	94	1,10-vii	82	74	E; SE; SW	SW; W; S	6·9	0·33
Sibi	110·0	122	5-vii	46	..	S; SW; SE	..	1·7	0·30

From the above data, it may be seen that fairly high maximum temperatures were registered in Baluchistan as early as the last week of April, and that high temperature conditions associated with low humidity were met with during the greater part of May and June. It is probable that, in reaction to these unfavourable factors, locusts had been feeling the urge for migration from Mekran. Under ordinary conditions the dominant wind of this region in the afternoons, *viz.*, the south-west wind from the coast, would carry them eastwards into Sind and South-west Punjab. On the other hand, whenever the strong north-westerly '*Gonch*' winds developed, they would be carried from the interior south-eastwards into the coastal areas, such as Pasni and Gwadar, as had happened early in June at Pasni. In any case, however, most of the locusts would sooner or later be transported by the south-west wind by stages into Sind and Rajputana.

IV. *Autumn Period*—1938.

(a) *Sind—Rajputana area.* 1. *The Southern desert areas.* There was no rainfall in autumn in any of the southern areas.

At Chachro, fair numbers of locusts mostly of the new brood were met with during September, for the new generation had begun to appear by the middle of August. As a result of the August rainfall, further oviposition had apparently occurred at Chachro, and hoppers were noted there up to the middle of October. During a tour in September, Bhatia noticed a fairly good number of adults and hoppers in the Thar-Mallani area. Adults and hoppers of *Locusta* were also found at Chapur-Khosa. Locusts had begun to disappear from the Sheo-Mallani areas by the beginning of October, but were present in good numbers in the Chachro area till the middle of the month, though towards its close few were seen either at Chachro or in the Thar area. In November, except for two specimens collected at Chapur-Khosa on the 19th, no locusts were found either at Chachro or in the Thar-Mallani area.

The population density for September, October and November at Chachro averaged 47, 107 and *nil* per sq. mile. The disappearance of locusts from the Thar-Mallani area by the middle of October and the appearance of specimens with mauve tinge on the wings on the Ambagh reks from 23 October onwards are apparently obvious incidents of autumnal migration.

Biometrical index of Thar-Mallani population.

September-October-November 1938: (34 specimens) 48*S*: 52*T*:*OG* ::61(6):39(7).

2. *The Northern Desert areas.* Except for light showers in the third week of September in parts of the Bikaner area, dry weather prevailed throughout autumn. In fact, owing to the failure of the monsoon in August and September, famine conditions prevailed in many parts of the desert area.

At Sardarshahr Outpost, no locusts were seen throughout the autumn but for a stray individual found on 9 October, possibly brought in by dust-storms of 5 and 6 October. No breeding was observed anywhere. At Nokh, fair numbers of locusts were noticed in September and the first fortnight of October—mostly the new brood of the monsoon. In addition, small numbers of hoppers were also met with till 12 October.

A few adults and hoppers were similarly noticed at this period in east Jaisalmer and west Bikaner. One locust was found on 16 September also in the Sri Ganganagar area.

Fair numbers of *Locusta migratoria* were found in various places, especially in the canal areas of Sri Ganganagar and Hanumangarh, and some also in the Sirohi, Mehsana and Kathiawar areas in the south, and near Ambala in the north.

In November, few locusts were noticed, except for three found during the first fortnight, and two during the second, around Nokh. A few *Locusta* adults were also found during surveys.

Biometrical index: September-October 1938: *East Jaisalmer and West Bikaner areas.* (18 specimens) 38S:17T:OG: 22(6):78(7).

(b) *West Sind—Kachhi area.* Except for one specimen of *Locusta migratoria* found in a field at Dadhar on 2 September, no locusts were found anywhere during autumn.

(c) *Lasbela—Karachi area.* As already mentioned, good rainfall occurred on the coast between Sonmiani and Karachi at the end of August, but as the depression did not penetrate further up, there was no rain in the interior of Lasbela or the Hingol area. There was no rainfall in autumn.

With the fall of rains, oviposition would appear to have been stimulated. Several locusts with sand-grains and froth on the valves of the ovi-positor were noted during September. Hoppers were met with during the month, and as the hoppers found at Gadani on 17 and at Lak Baduk on 19 September were of the fifth stage, and as, moreover, hyline-winged adults were collected on the 14th at Bagori, it is obvious that the earliest egglaying had occurred soon after July, rainfall.

It is interesting to record here that a yellow-winged adult—evidently of the old brood—was collected on 2 September at Adampir near Naka Kharrari, with greenish body and elytra. This coloration is presumed to be due to the influence of the lush green vegetation that had sprung up after the good rains of August. Later on a few adults of the new generation with similar greenish body coloration were also found.

During September, locusts were found mostly along the coastal strip from Gadani to Sonmiani and Liari, and only two were met with in the Hingol area.

A few hoppers were met with on the reks during October and none after 13 November. With the appearance of the new generation, there was an increase of population all over the coastal areas. While the average density was 19 per sq. mile for September, it was 226 per sq. mile for October and 414 for the first fortnight of November. In the second fortnight, however, it was only 122 per sq. mile, as with the development of the dry north-easterly winds much of the population had been apparently swept out of the area.

In October, while the forms noted during the first fortnight had hyaline or light yellow wings, being evidently locally bred ones, those found during the second, had pink or mauve wing bases in many cases, indicating that the usual autumnal migration had set in. Migrants were noticed in fair numbers during November and December at Ambagh.

In November, a fieldman found a few locusts with transparent wings at Khandewari, Sangal and Pohr, presumably all recently bred ones.

Karachi area As a result of good rainfall in July and August, light breeding occurred in the Band Muradkhan bank of the Hab River and several fresh adults were met with in September, and a few stray ones in October and November. One of the two specimens collected on 2 November had mauve-coloured wing-bases. Unlike the previous year, no locusts were met with on the beds of various streams, such as the Baran, during the autumn months.

Locusta migratoria. Both in the Ambagh Rek area (including Lak Baduk and Gadani) and along the banks of the Hab River, numerous specimens of adults and hoppers of the solitary phase of the Migratory Locust were noticed during September and October. They were found mostly in grass patches in which they occurred in small concentrations. Apparently the rainfall in July-August had stimulated breeding.

Biometrical index: Ambagh Reks.

September 1938: (34 specimens) *65S:35T:OG: :79(6):21(7).*

October 1938: (18 specimens) *28S:72T:OG: :83(6):17(7).*

November 1938: (21 specimens) *57S:33T: 10G: :76(6):24(7).*

(d) *The Mekran area*: 1. *The Interior of Mekran: Kulanch-Dasht and Kech Valley.* No locusts were met with.

Panjgur area. None was found anywhere except in Nag-i-Kalat, where on 23 and 24 October, four adults with light yellow wings but without any mauve tinge were observed, and on 19 November one with mauve wing-base near Pissi—possibly a migrant from the east.

Kolwa area. Between 9 and 19 September, several hoppers and fresh adults were met with, confined to a sector roughly enclosed between Rodkan, Chambar-Kalat and Sigak. The hoppers were mostly in the penultimate stage, though a few were of the I and III instars. The largest number of adults were noted in the Sigak area. Most of them had hyaline wings, but some found on the 10th at Rodkan, and on the 15th and 16th near Chambar-Kalat had yellow wings with mauve tinge at base. One of them had a few colonies of green algae. They were of the old brood and were probably migrants. In addition to the good rainfall in July, it was found on enquiry that some rain had also occurred at the end of August, and it is presumed that the latter had been responsible for the appearance of the younger hoppers noticed in September, the main brood being obviously connected with the July rainfall.

During a visit in mid-October, locusts were found mostly in the form of light concentrations. In the Sigak area, as many as 41 adults were collected on 18 October from cultivated fields. Most of them were hay-yellow in colour, and had hyaline or light yellow wings (evidently locally bred ones), though a few had yellow wings. A month later, no trace of locusts could be found. Presumably the *Gorich* winds, which prevailed in November in Mekran, had swept them out of Kolwa.

Biometrical index: Kolwa.

September-October 1938. (60 specimens) *72S:28T:OG: :44(6):56(7).*

The population was mostly a locally bred one; and *solitaria* ratios and 7-stripes were dominant.

2. *The Mekran Coastal reks.* There was no rainfall during autumn except for 0·06 in. at Jiwani and 0·23 in. at Pasni Station on 20 November. Very few locusts were to be seen on any of the reks as may be observed from the figures of density tabulated below:

Areas	September	October	November
Ormara	5	5	Nil
Pasni	12	7	2
Gwadar	2	2	3

In September, out of 10 locusts collected on the Pasni reks, only one (24-ix) had a tinge of mauve at wing base. In spite of the drought a single hopper of the IV instar was collected on the top of the Mastani rek on a Marrand bush. It is presumed that this was the result of some stray oviposition that had occurred, as in 1935, on moist sand patches of the dune undulations laid bare by the wind.

In October, a few specimens with mauve wing-bases were found at Ormara, Gwadar and Pasni, and a few more at Pasni and Gwadar in November. The appearance of these may be taken to represent feebly the usual autumn migration from the east. The paucity of the migrant population is strictly in accordance with the very light breeding noticed in the Rajputana deserts.

Biometrical index. September-October-November 1938: (18 specimens) *71S : 29T : OG : : 56(6) : 44(7).*

Meteorological Factors governing Autumn Migration

Owing to a deficiency of monsoon rainfall, locust breeding was very light in 1938, and the comparatively small adult population that resulted therefrom was found disappearing from the desert areas early in October. The following data extracted from the Monthly Weather Review of the India Meteorological Department would give an idea of the nature of the climatic changes experienced in the autumn of 1938.

Monthly Meteorological Data for the period August-November, 1938, *in Western Rajputana*

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain (inches)
	Mean Max :	Highest Max.	Date of Occurrence	8 A.M. (per cent)	5 P.M. (per cent)	8 A.M.	5 P.M		
	(Degrees Fahrenheit)								
August 1938									
Sri Ganganagar	101·7	106	9,24-viii	60	39	SW;W;S	SW;W;E;SE	0·6	1·05″
Bikaner	99·5	104	9,24-viii	67	43	SW;W	SW;W;SE	2·8	2·60″
Jodhpur	93·7	98	15,16,31	81	51	SW;W	SW;S	7·6	1·68″
Barmer	92·6	97	4 days	76	52	SW;W;S	SW;S	7·0	0·53″

Monthly Meteorological Data for the period August-November, 1938, in Western Rajputana—contd.

Localities	Maximum Temperature			Humidity		Dominant Wind Direction		Cloud Amount	Rain (inches)
	Mean Max: (Degrees Fahrenheit)	Highest Max.	Date of Occurrence	8 A.M. (per cent)	5 P.M. (per cent)	8 A.M.	5 P.M.		
September 1938									
Sri Ganganagar	100·7	109	17-ix	51	29	SW;W	SW;W;N	0·6	0·15"
Bikaner	100·1	107	16-ix	55	29	SW;W;NW	SW;W;NW	1·6	Nil
Jodhpur	98·9	108	15-ix	65	32	SW;W;N	SW;W;S;N	3·1	0·19"
Barmer	95·8	106	16-ix	70	37	SW;S;W;Cm	SW;S	3·1	Nil
October 1938									
Sri Ganganagar	96·3	105	3,4,5-x	42	22	E;S;SE;NW	N;NW;W	0·3	0·27"
Bikaner	97·1	105	4 days	39	22	SW;SE;S;Cm	NW;SW;W;N	0·6	Nil
Jodhpur	99·2	107	2-x	39	16	Cm;SW;NE;S	SW;W;NE	0·3	Nil
Barmer	97·1	105	1,2-x	53	28	Cm;SW;NW	SW;W;NW;S	1·2	0·14"
November 1938									
Sri Ganganagar	82·6	89	1,3,12-xi	43	27	SE;N	NW;N	0·2	0·02"
Bikaner	82·8	90	1,3-xi	44	28	SE;S;W	N;NW;W	0·5	Nil
Jodhpur	87·1	95	1-xi	25	12	NE;Cm;N	NE;W;Cm	0·6	Nil
Barmer	86·0	93	1,2-xi	38	19	NW;N;Cm	NE;Cm;WSW	0·7	Nil

The points noteworthy in the above data are the following:—(1) The highly defective precipitation in August and a more or less absolute failure of rain in September, associated with a fall of humidity and the development of high temperatures. In the northern areas the skies were practically cloudless. (2) In October, high temperatures accompanied by dry northerly winds prevailed during the first week in connection with a cyclone in the north Arabian Sea, but in spite of a subsidence of temperatures in general during the rest of month, conditions of saturation deficiency were further accentuated. (3) In November, there was a further fall of temperatures, though conditions of drought continued. Owing to the lack of rainfall in August and September, there was no late breeding, and most of the hoppers had turned into adults by the beginning of October and had left the area by the end of the month, in consequence of the unfavourable atmospheric conditions then prevailing. Over-wintering did not, therefore, occur in the desert in 1938-39.

Summary of events during 1938

Moderate rainfall was received in the Mekran areas during the months of December, January and February. The amount of precipitation varied in different places, but the total was below average everywhere. There was little rain in Kachhi and Rajputana during the spring months.

A fairly high population of over-wintering locusts was found in the Chachro area, where even hoppers were noticed over-wintering in small numbers. A small locust population was likewise present in the winter months in the Sardarshahr area. By April, however, most of the locusts disappeared from the desert areas.

A large over-wintering population was present also in the Lasbela and Mekran rek areas, most of which were found to have developed colonies of green algae on the wings. In the interior of Mekran, locusts were not noticed in December and January, but began to appear early in February, presumably by migration from the coast. Fair numbers were seen in Kulanch and Dasht in February and considerable breeding followed, especially in Kulanch during March and April. By March and April, locusts reached Kolwa and Panjgur areas, and occasioned light breeding there in April and May. Hoppers were found in the Gar and Nagi-Kalat areas even in June and July. As a result of the receipt of winter-rainfall, light to moderate breeding was noticed on the coastal reks of Pasni, Ormara and Gwadar. In the Lasbela areas, hoppers appeared only in the Nakhetri area, and there was no breeding in the interior as in 1937. In the Kachhi area, there was little rainfall, and consequently there was no spring breeding, but in the Bolan valley some breeding was found to have taken place in areas of cultivation.

The monsoon began fairly early, but rainfall was confined only to parts of Rajputana in June. In July, rainfall was nearly general, but in August the monsoon was defective and in September it proved a failure.

There was evidence of summer-migration of solitary adults in June in Kolwa and on the coastal reks of Mekran and Lasbela. In the desert area, the first migrants were noted the northern fringes of the Rajputana desert, in northern and eastern Bikaner. At Barmer, where early showers were received in May and June, hoppers were found in small numbers in June-July, but there was little subsequent breeding there. At Chachro and Nokh, there was but light rainfall till the middle of July and few locusts were seen at these places. With the fall of heavy thunder-storm rain in the latter part of July, locusts were apparently carried into these areas during August-September. Owing to the general failure of rain in August-September, there was no late breeding during the monsoon period, and consequently no second summer generation. With the setting in of a dry hot spell in September-October, most of the adults of the new generation left the desert area, so that few locusts were to be seen there in November.

As a result of good rainfall in July, light breeding occurred in parts of Kolwa during August, September and October. Similarly, in the Lasbela area, fairly good breeding was noticed in the Ambagh-Gadani coastal areas during the autumn months in the wake of good showers received in August.

Individuals with mauve or pink wing-bases were observed in small numbers at Ambagh from the 23rd October onwards, and on the Pasni and Ormara reks as well as in the interior of Mekran a few such specimens were seen in October and November. These are presumed to be faint indications of the usual autumn migration of locusts, the development of which appears to have been feeble in close accordance with the restricted breeding noted in the desert areas as a result of defective monsoon rainfall. There was, likewise, very little of over-wintering in the Lasbela-Mekran areas during the winter of 1938-39.

As in 1937, a fairly close association of both the desert and the migratory locusts with reference to their occurrence and breeding at many places in the desert areas and in the valleys of Baluchistan, was observable, which is presumably due to a similarity in their response to changes in seasonal conditions.

STATEMENT VIII

Results of Locust Surveys—1938

(The figures represent the average density of population per square mile for the whole month in the areas surveyed and 'H' indicates occurrence of breeding)

Seasons	Months	BALUCHISTAN										SIND—RAJPUTANA DESERT							
		MEKRAN							LASBELA										
		Gwadar : Pishukan	Pasni Reks (Int-surveys)	Ormara	Kech-Buleda	Panjgur	Kulanch Dasht	Kolwa	Hingol	Ambagh Reks. (Int : surveys)	Hinidan Beja	West-Sind & Kachhi	S. W. Punjab Bahawalpur	Chachro (Int : surveys)	Thar-Mallani	S. Jaisalmer W. Bikaner	Nokh (Int : surveys)	East Bikaner	Sardar Shahr (Int : surveys)
Winter	Dec 1937	42	56	40	9	Nil	2	Nil	150	300	8	Nil		H 165	H 567	5	7		199
	Jan 1938	34	68	860	Nil	Nil	15	3		483	6	72		343	171	Nil	3		37
	Feb 1938	55	89	1210	9	7	227	H Nil	124	345	Nil			H 454	101	20	6	Nil	51
Spring	March 1938	165	H 160	H 311	Nil	Nil	H 133	71	H 461	198	Nil	36		226	5	Nil	Nil		3
	April 1938	H 45	H 276	H 149	Nil	Nil	H 79	H Nil		71	Nil	8		21		Nil	Nil	Nil	Nil
	May 1938	24	H 198	H 115	Nil	14	H 134	Nil	H 17	98	Nil	H 21	Nil	Nil	Nil	Nil	Nil		Nil
Summer	June 1938	11	H 59	43	Nil	H 46	7	31		21	Nil	Nil	42	Nil	H 11	Nil	Nil	7	6
	July 1938	7	52	38	Nil	H 91	2	3	3	8	Nil			8	H 4	21	34	Nil	Nil
	August 1938	3	13	15	3	33	Nil			6	H Nil		H 32	H 46	6	27	H 19	H 2	Nil
Autumn	Sept 1938	2	12	5	Nil	Nil	Nil	H 78	8	119	H 38		2	H 47	H 48	H 6	H 27	Nil	Nil
	Oct 1938	2	7	5	Nil	9	Nil	164		H 226	H 61		Nil	H 107	6	H 5	H 26		2
	Nov 1938	3	2	Nil	Nil	3	Nil	Nil	14	H 279	H 62			Nil	5	Nil	6	Nil	Nil

YEAR 1939

Weather notes

Winter rainfall in 1938-39. The earliest winter disturbances began to appear in October 1938 and as many as 54 were recorded up to June 1939. There was only light rain in November at places in Mekran, but better rainfall in December. In January widespread rainfall occurred in Baluchistan, mostly in the third week (Pasni three inches). Western disturbances were active during the latter half of February and caused widespread rain in Baluchistan, Sind, Punjab and Rajputana. Pasni received a total fall of 3·96 in., and Ambagh 4·42 in. in February. In the second fortnight of March also, widespread rain occurred in Baluchistan, Sind and Punjab (Pasni 1·75 in. and Ambagh 2 in.). Fairly good showers were recorded in parts of Baluchistan even in April. The winter period proved, therefore, to be one of more than average rainfall, except perhaps in the Gwadar-Jiwani area.

Monthly Rainfall Data for Winter-Spring season 1938-39

Localities	Nov. 38	Dec. 38	Jan. 39	Feb. 39	March 39	April	May
Iran							
Jask	0·12	0·47	1·73	1·58	0·65	0·60	...
Charbar	...	0·02	...	5·30	...	0·73	..
East Arabia							
Muscat	...	0·79	...	2·97	...	...	...
Sharjah	...	0·88	2·31	1·41	0·03	0·45	...
Baluchistan							
Pasni	0·23	1·27	3·19	3·96	1·66	0·12	...
Jiwani	0·06	0·27	1·48	1·28	0·28	1·02	...
Ormara	..	0·39	2·70	4·05	0·58	0·72	...
Turbat	0·17	0·90	0·33	4·26	0·70	0·85	...
Panjgur	...	0·59	0·94	2·00	1·58	0·05	...
Sibi	...	0·13	0·04	4·28	2·54	...	...
Bela	...	...	...	2·99	6·86	0·74	0·37
Ambagh	...	0·35	...	4·42	2·14	...	...
Quetta	0·30	0·43	1·56	6·07	3·66	0·66	0·47
Rajputana							
Sriganganagar	0·02	...	0·09	1·66	1·15	0·02	0·10
Bikaner	...	0·06	...	0·75	0·39	...	...
Jodhpur	...	...	...	1·89	0·07	0·04	...
Barmer	...	...	...	1·59	0·06	0·04	...

From the above data, it is seen that outside the limits of British Mekran, rainfall was not above average except at Charbar, and apparently conditions were not very much favourable for intensive breeding. Rainfall in the Lasbela area was, on the other hand, much above the average.

Observations of Locust Distribution in 1939

I. *Winter period 1938-1939*

(December 1938 to March 1939)

(a) *Sind-Rajputana area and* (b) *Kachhi area.* There was fairly good winter rainfall in many of the Sind-Rajputana areas and in Kachhi in February 1939.

No locusts were met with, however, in any place between December 1938 and March 1939.

(c) *Lasbela area.* Ambagh recorded 0·34 in. of rain on 19 December. There was no rainfall in January, but in February heavy rainfall (4·42 in.) was received at Ambagh and in March (II fortnight) about 2·15 in. Rainfall appears to have been wide-spread in the Lasbela area, and was unprecedentedly heavy.

In December, 1938, comparatively small numbers of locusts were met with on the Ambagh reks and the Lak-Baduk and Gadani areas. Most of them had mauve or pink bases and were apparently migrants. In January no locusts were met with in the Gadani and Hingol areas, but on the Ambagh reks nine were found in the course of the month. Most of them had a tinge of blue or violet on the wings, and six of them had a fair number of very young colonies of green algae. In February, larger numbers were seen in the Lasbela area. A few were found in the Bela-Uthal area and at Habnadi, and about 30 specimens were noticed on the Ambagh reks. Many had bluish or mauve tinge. In March, the locust population was found to be gradually disappearing. During the first fortnight, 11 locusts were observed with mauve bases, but none during the second. None were found in the interior of the country in the Bela and Khandewari areas. Out of four specimens collected during the first week of February, one had traces of young green algae.

February 1938-39: *Lasbela area.* (30 specimens) 69*S*:31*T*:*OG*:66(6):34(7).

(d) *The Mekran area.* The winter rains began fairly early in Makran and were, on the whole above the average in most parts of Baluchistan. Light falls occurred in December and were followed by fairly good falls in January mostly along the coast. Heavy rain was recorded in February both along the coastal areas (except Jiwani) and in the interior, Turbat receiving over four inches. There was fairly good precipitation all over Mekran in March and a few light showers in April.

(1) *Mekran interior.*—In December, one locust was found at Rodkan in Kolwa on the 13th and had mauve coloured wings. At Nagi-i-Kalat, three specimens with blue tinge were noticed on the 16th.

In January no locusts were encountered in the interior, but in February one specimen was found at Shah Kahan in the Nasirabad area in Kech valley.

In March, two locusts were detected in Kolwa, and one locust near Suntsar about the 16th.

(2) *Mekran Coastal areas.*—In December a single locust was caught at Rumra in the Ormara area on the 1st and another at Jiwani on the 6th. Both possessed mauve-coloured wing-bases.

In January a locust with mauve base was found at Chur in the Pasni rek area on the 1st, and another on the 7th in the Gurrani rek. The latter had brownish yellow wings and had colonies of green algae. One specimen with distinct mauve base was collected in the second week between Suntsar and Gwadar. No locusts were located in the Ormara area.

In February two yellow-winged females were noted, one of which showed distinct signs of having laid eggs.

In March, 12 locusts of the old brood were observed on the Pasni reks in the course of the month. On the Ormara rek areas, four locusts of the old brood were similarly found. One locust with a mauve base was noted in the Pishukan-Jiwani reks.

The population in the Mekran areas was, thus, very thin in spring so that the breeding that actually followed was not commensurate with the excellent winter rainfall, which, on the analogy of the events of the year 1935, was high enough to have brought about incipient swarming.

Biometrical index of the populations.

As the collections of the period in Mekran were not available for examination, no statement can be made.

The closure of the Scheme.

This brings us to the end of an account of continuous observations, covering a period of over eight years on the distribution and activity of the locust in the Indian region, made by the staff employed on the locust research scheme of the Imperial Council of Agricultural Research up to 31 March 1939, when it was finally brought to a close.

From 1 April 1939, desert observation work for keeping a watch on the developments of the locust was taken over by the new Locust Warning Organization sanctioned by the Government of India, and placed under the Imperial Entomologist at the Imperial Agricultural Research Institute, New Delhi. A good part of the staff employed under the old scheme was, however, absorbed in the new organization, which thereby secured for itself the initial advantage of a personnel with full experience of locust survey work.

Although work done in the course of eight years under the old scheme had led to definite results of fairly high scientific value and practical importance, it was deemed necessary that the field observations should be continued during a series of years so as to confirm or modify the conclusions so far reached. In fact, the practical value of the results of these investigations could be gauged only when, at the beginning of an outbreak, the locust warning organization could find itself in a position to spot the outbreak centres at an early stage, and bring them under control, thus smothering the infestation before it could break out.

SECTION IV—EXPERIMENTAL : ECOLOGICAL : AND BIOMETRICAL STUDIES

CHAPTER I

EXPERIMENTAL STUDIES OF THE DESERT LOCUST

IN the course of the observations carried out, during the recent swarm-free period 1932 to 1939, on the behaviour of the solitary phase of the locust in its natural haunts, the need of a detailed knowledge in respect of how far and how exactly its life activities were affected by the different factors of its environment was greatly felt. The main consideration in a study of the solitary phase being the determination of the conditions stimulating a transformation into the gregarious phase, its various aspects were carefully examined, and as the central core of this problem apparently revolved on the factors that contribute to the rapid building up of the huge populations—characteristic of the *gregaria* phase, various questions such as the following had to be taken up for immediate consideration: What is the number of generations possible in the course of a year? Does a diapause occur in the life-history of the desert locust? What are the factors affecting its sex-maturation and the length of the egg and hopper stages? Does the locust have food-preferences?

It was obvious that many of these questions could not be solved satisfactorily except under the controlled conditions of a well-fitted laboratory, and, in fact, some of these problems were already under investigation at the laboratories of the Lyallpur branch of the Imperial Council's scheme. As, however, it was considered possible, even in the absence of elaborate equipment, to devise simple experiments in the actual habitat of the locust to observe how it reacted to changes in its environment, experimental studies of the solitary locust kept in breeding cages amidst the desert habitat were undertaken at some of the locust observation stations such as Pasni, Ambagh and Chachro.

The following items were under experimentation at the different stations during the period 1932-38:

1. The number of successive generations possible in a year.
2. The length of incubation period under semi-natural conditions correlated with soil temperature.
3. The length of the post-embryonic period under semi-natural conditions correlated with average air temperatures.
4. The influence of quality of food on hastening the sex-maturity of the adult.
5. The influence of quality of food on the rapidity of growth of hoppers.
6. The Food Preferences of the locust.
7. The development of eye-stripes in hoppers.
8. The effect of crowding on the number of eye-stripes.
9. Coloration of locusts in relation to a change of environment.
10. Effect of sunlight on the coloration of the wings

I. The maximum number of successive generations possible in a year

In gauging the powers of the locust to build up the dense populations characteristic of the gregarious phase, the main point to be determined is the extent of its capacity to breed rapidly and intensively. If the desert locust should happen to be subject to a compulsory diapause in the egg or adult stage, as is the case with certain other species of locusts, the rate of multiplication would naturally be slow, as thereby only a single generation would be possible during the year. Husain and Ahmad [1936] have, however, conclusively proved that there is no diapause in the desert locust in any stage of its development, so that, in the absence of a compulsory diapause, there is nothing to prevent the locust from going through several successive broods during the year and increasing rapidly in numbers. They have further shown that as many as eight successive generations may be obtained within a year at a constant temperature of 40°C., seven generations at 36°C., and five at 30°C. Under natural conditions, however, constant temperatures are but rarely met with, and there is always a considerable fluctuation of temperatures—diurnal as well as seasonal, so that the length of duration of a brood would naturally vary a great deal in accordance with the prevailing temperatures.

In nature, the main factor in the breeding of the locust would appear to be the presence of an optimum amount of moisture in the soil, which under natural conditions is dependent on requisite rainfall, and as apparently the mass-multiplication of the locust depends on optimum conditions of rainfall, it was considered desirable to measure the potentialities of increase possessed by the insect by rearing it under confinement in cages in the actual desert environment, but providing it with the optimum amount of soil-moisture. Pairs of locusts kept in cages and provided with fresh food and with wet sand at the bottom were found breeding satisfactorily and producing a succession of generations, although in nature in the breeding grounds round-about only a single generation was observable.

The cages used for the 'generation' experiments were of the type designed for making observations on oviposition. The earlier type was 9 in. square and about 18 in. high, divided into a lower compartment with glazed sides filled with sand, and an upper one with wire-gauze top and sides and fitted with a hinged door on one side. Two or three pairs of locusts of known age were introduced into the upper compartment, where their activities were kept under regular observation. Eggs were laid in the sand bed provided and the place was oviposition was promptly marked with a flag for keeping a watch for the date of hatching. Since 1935, a modified type of cage of slightly larger dimensions was used. It was of the same height (18 in.) but the sides were 12 in.×12. instead of 9 in.×9 in. The upper compartment was 12 in. high, while the lower one was 6 in. high and a sliding board fitted with holes to receive tubes of 2 in. diameter formed the floor of the upper chamber. Both the upper and the lower compartments were fitted with hinged doors on one side. As ovi-position readily occurred in tubes of moist sand, it was found very convenient to remove those containing the deposited eggs for observation and replace them by fresh tubes. The cages were kept in the open either on the ground with antpans protecting their legs from the incursions of ants, or several cages together on low benches duly fitted with ant-pans (*vide* pl. 20). The locusts were fed morning and evening with fresh food, generally the commonest wild food-plant procurable in the neighbourhood, or in its absence with either cabbage, lucerne or jowar leaves, and the earliest date of pairing and

oviposition was duly noted. Egg masses were marked and kept separate and the date of hatching watched for. The earliest batch of hoppers was kept in a separate cage and carefully reared, noting down the earliest date of moulting at each stage. The earliest adults produced by these hoppers were separated in pairs and used for rearing the subsequent generation.

At Ambagh, successive broods were reared from a stock that became adult in October 1935, and by September 1938, the eighth generation was under rearing. There were some indications to suggest that the slow development of breeding was possibly due to continued in-breeding from the same stock. At Pasni, however, the generation experiments were started every year with a fresh stock of locusts. In 1933 and 1934, cages were started in September 1932 and 1933 respectively, and rearing was continued till November 1933 and 1934, by which time four complete generations were passed through. In 1935, the original pairs selected in September, 1934 happened to die by December, and as no fresh stock was available till February 1935, only three generations could be obtained that year. In subsequent years, the system was changed. As, in nature, no breeding occurs at Pasni till the over-wintered migrants start laying eggs in February-March, locusts collected from the field in January-February each year were used for starting the experimental cages. At Chachro these experiments were carried out only once in 1935.

From the results tabulated in Statement A, the following deductions may be made:—

1. During late spring and in summer, when the average monthly mean temperatures vary from 28° to 30°C., the periods of sex-maturation, egg incubation and hopper development are shortest; in spring and autumn, on the other hand, when the means range from about 22° to 26°C., they tend to be much longer, and, in winter, development is extremely slow. In summer, sex-maturation may occur in 3 to 4 weeks, eggs may hatch in about 14 days and hopper development may be completed in about 31 days.

2. In midsummer, the duration of the life cycle, from oviposition by the parent generation to egg laying by the progeny, may be completed in about two months and a half, but is much longer in spring, autumn and winter, so that it is not possible to have more than three successive generations during the year. At Pasni, a fourth generation was obtained in the course of the experiments in 1933 and 1934, but the total time taken for the completion of four successive broods was about 14 months. At the utmost, one might have seven generations in the course of two years.

3. At Pasni, there is usually only one brood in the year in the spring months, and as summer is a period of drought, there is no breeding then. On the other hand, Ambagh and Chachro fall within the zone of summer rainfall and breeding occurs only in summer, and there is no breeding in winter and spring which are periods of drought. Usually, locusts tend to leave areas of drought and migrate elsewhere. However, whenever

there is good rainfall in summer at Pasni, as had happened in 1932, breeding may take place there. Moreover, in years of heavy rainfall like 1933, 1935 and 1939, young hoppers were being met with at Pasni in certain special areas from June to September, although none was noticed on the general *rek* areas after May. On investigation, this was found to be due to egg laying in wet patches of dunes laid bare by the heavy south west wind, and would indicate that breeding may, under such special conditions, continue in these areas in spite of the absence of rainfall. Similarly, at Ambagh light breeding was noted in spring in 1939 as a result of exceptionally heavy rainfall, though usually no breeding occurs here in spring.

4. Although there is usually little possibility of there being more than a single generation at places like Pasni and Ambagh in an ordinary year, the powers of migration possessed by locusts enable them to reach places where, more often than not, they are able to lay eggs immediately. New adults emerging in April on the coastal *reks* may reach the interior valleys of Mekran and start a new brood in May, and adults of this new generation appearing by the end of June, may migrate to the Rajputana desert in July and lay eggs during the month. Adults of this generation appearing in September may under favourable circumstances start a new brood by the end of that month. Theoretically, therefore, there is the possibility of four successive generations following one another in the course of the year, though ordinarily not more than three broods can be expected.

II. *The length of the incubation period under semi-natural conditions correlated with soil temperatures*

Eggs of locusts are deposited in fairly soft sandy or loamy soils, generally at a depth of about 4 in. and their development is dependent on the existence of optimum conditions of soil moisture and soil temperature at that depth. Under natural conditions in the desert, the requisite moisture conditions are obtainable only for three to four weeks after good rainfall, and usually the locust lays its eggs only when the soil moisture conditions are satisfactory. On the other hand, conditions of soil temperature are affected not only by the diurnal and seasonal fluctuations of atmospheric temperatures, but also by the intensity of solar radiation. Whereas under the controlled conditions of a laboratory the precise effect of constant soil temperatures on the duration of the incubation period can be determined, under field conditions, it is possible to arrive only at a rough correlation of the length of the incubation period with the average of mean daily temperatures prevailing during this period of time.

In the course of various experiments undertaken at Pasni in connection with a study of the feeding and breeding habits of the solitary locust under semi-natural conditions in cages, the actual times of egg-laying and hatching were noted in a large number of cases and correlated with the average mean temperature of moist sandy soil at four-inch depth observed in cages during the period of development. Although from the very nature of the conditions, the correlations cannot be claimed to be accurate, the results tabulated below may give one an approximate idea of the length of the incubation period that may be expected under particular types of seasonal conditions in nature.

In the results tabulated in *Table I*, the optimum soil moisture was maintained in all cases by periodically moistening the soil containing the egg masses. In each case, the average of the daily means for the whole period was calculated, and wherever the results included fractions they were reckoned in terms of the nearest whole numbers (for instance, 25°F

includes all averages from 24·5°C. and 25·4° C.). For each degree, the average duration was calculated when there was more than one record.

TABLE I

Incubation period in relation to soil temperature at 4 inch depth showing the difference in values for each rise of a degree Celsius.

(Compiled from data for the years 1932—1937)

No. of records	Soil temperature of moist sand at 4 in. depth (in degrees Centigrade)	Incubation period in days	
		Individual records	Averages (in days)
2	19	73,70	71·5
1	20	48	48
1	21	37	37
6	22	37,36,34,36,32,29.	3
3	23	28,29,29·5.	28·8
7	24	27,27,26,29·5,27,25,27.	26·9
3	25	25,24,25.	24·7
11	26	25,25,24,22,26,26,25,22,23,28,25	24·6
19	27	23,20,21,23,21,20,23,25,22,23,24,24,21,24, 20,21,20,20,20.	21·8
9	28	18,19,22,22,19,19,19,18,19.	19·4
11	29	20,19,19,16,17,18,17,18,19,18,19.	18·2
12	30	16·5,14·5,14,17,17,17,17,16,17,17,17,16.	16·3
24	31	16,15·5,15,14,16,16,13,16,15,18,15,16,16, 17,16,14,17,16,14,15,14,15,14,15.	15·4
13	32	15,15,15,16,13,15,15,14,15,15,15,14,14.	14·7
14	33	16,15,14,14,16,14,14,12,14,15,15,14,14,15	14·4
1	34	13	13

The tabulation of results shows that with a rise of soil temperature there is a gradual fall in the duration of the incubation period. These results have been plotted in a graph (*Vide* Text—Fig. 2) with the soil temperatures as abscissae and the duration of incubation in days as ordinates, and the points would appear to range themselves on either side of a curve which rises rather steeply below 25°C., indicating that the incubation period, which ranges from 14 to 25 days between 34° and 25°C. tends to grow longer and longer as the temperature falls, till at about 19°C. there is apparently no development.

There is a fairly high variation noticeable between individual records in regard to the length of the incubation period for the same temperature, which is to be attributed to the comparative degree of fluctuation of temperatures met with in each particular record.

TABLE II

Showing correlation between length of post-embryonic period and mean atmospheric temperature.

(Compiled from data of 1933—1935)

Temperature Degrees Celsius	Minimum duration of post-embryonic development (in days)			
	1933	1934	1935	Averages
20°		85		85
21°	83			83
22°				..
23°		54		54
24°	44	54		49
25°	41,40		43,42,39,37	40
26°	35,36		36	36
27°	34,36	39		6
28°			37	37
29°			38	38
30°	34	36,34,34		34
31°	32			32

In *Statement B* appended, records of various cases of hatching observed at Pasni during the years 1935, 1936 and 1937, have been given along with notes as to the length of the egg-stage, the range of soil temperatures observed and particulars of the number of eggs, the colour of the hoppers and the sex-ratio of each particular batch (as determined from the terminal appendages of the first stage hoppers). The difference in the colour of the hoppers at hatching time would appear to be an intriguing problem, as very often green hoppers have been found to emerge from eggs laid by *gregaria* adults and black hoppers from those of *solitaria* parents. The sex ratio would appear to be an important character in connection with mass multiplication, since hatchings in which females preponderate may be expected to bring about a more rapid increase of population.

III. *The length of the post-embryonic period under semi-natural conditions correlated with average atmospheric temperatures*

In the course of experimental work at Pasni, notes were kept in several cases on the temperatures prevailing during the post-embryonic development of hoppers. A study of these has been made and the results have been tabulated (*Table II*) to show the correlation between the average daily mean temperature and the length of the hopper period.

Individuals belonging to the same batch of hatching, however, very rarely grow at a uniform rate, as some develop very quickly, while others take a considerable time to reach the adult stage. For purposes of convenience the shortest duration recorded has been taken for purposes of correlation.

The results obtained show that with every rise of the magnitude of a degree Celsius in the average temperature, there is a corresponding decrease in the duration of post-embryonic development. The shortest period recorded is 31 days at an average mean of 31°C., while at an average of 20°C., the duration is as high as 85 days.

In Fig. 7 (*Vide* Text Fig. 3) where the inverse correlation which is observable has been plotted, the co-ordinate points are seen falling on either side of a curve which rises fairly gradually for temperatures between 31° and 25°C., but shows a rather steep rise for those below 25°C.

IV. *Experiments on the effect of Quality of Food on the sex-maturity of adult locusts*

In studying the influence of the environment in bringing about the phase transformation of the locust, one of the important factors to be considered is the quality of the food available on the breeding grounds. It is fairly common knowledge that the locust shows a definite partiality to certain particular plants and that fresh succulent growths are preferred to semi-dry branches. As all factors contributing to a rapid succession of generations are of great importance in bringing about mass-multiplication, it was desirable to find out how far different food-plants had the effect of hastening the sex-maturity of young locusts and of inducing early oviposition. It was also of importance to ascertain if any of these food-plants had the effect of quickening the growth of hoppers and thus of shortening the growing period.

Experiments on sex-maturity

Bodenheimer (1932) in his article on the 'Gesammt-Okologie' of the Desert Locust makes the suggestion that fresh succulent vegetation found growing after rainfall may exert a powerful influence in quickening the

sex maturation of locusts. In order to test it, Dr. K. R. Karandikar confined pairs of locusts of known age in oviposition cages at Pasni in 1934 and fed them on fresh shoots of Marrand (*Heliotropium undulatum*). Although the sand-bed at the bottom of the cages had been kept quite dry, it was found that the locusts attained maturity in about two months and dropped their eggs on the surface of dry sand. On the other hand, in nature, there was no fresh Marrand anywhere on the Pasni reks, on account of the drought that prevailed there throughout 1934, nor were any mature locusts met with in the area.

On the basis of these results, further experiments were undertaken in 1935 at Pasni for testing the effect of different food plants on the stimulation of the sex-maturity of locusts. These experiments included (1) the use of fresh shoots of marrand as against shoots of old or semi-dry marrand, (2) Old marrand shoots wetted (to counter-balance the deficiency of water-content); (3) Old marrand kept in a moist atmosphere, and (4) fresh shoots of other food-plants. In 1936 and 1937, the experiments were restricted to comparative tests of fresh and old Marrand at Pasni, of fresh and old Kharzan at Ambagh, and to tests of various other important food plants of the locust at both places.

In addition, experiments were devised at Pasni to find out the relative amount of plant-food devoured by female locusts before laying the first egg-mass in the case of each different food-plant. As it was difficult, however, in the absence of elaborate equipment, to determine accurately the quantity of food eaten by locusts under observation per day in view of the complication due to driage and wastage, the faeces dropped by the locusts were carefully collected day by day, and weighed after drying them in a water-oven. It was presumed that the relative quantity of faecal pellets recorded for the different food-plants would give a rough indication of the relative quantity of plant-food consumed by the locusts. For these experiments, improvised cages consisting of hurricane-lamp chimneys closed on either side with wire-gauge were used with much advantage, as thereby the loss of stray pellets of faeces was largely prevented. These experiments were first carried out in 1936, and were repeated in the following year.

In the case of the 'quality of food' experiments, a pair of recently fledged male and female locusts were introduced into the cage and were examined day by day to note changes in the colour of the hind-wings. In fresh adults, they are always semi-transparent, but in the course of a varying period of time, depending on the prevailing temperature and the nature of the food, a yellowish tinge appears on them, which deepens in the course of a week or ten days. The yellow colour would appear to be a symptom of the onset of sex maturity, as at that stage the male is generally found to make its first attempt at courtship. By the time oviposition takes place, the wings usually assume a bright yellow colour, (Plate 21, Figs. 1, 3 and 4) and, in recording the results of these experiments, therefore, the appearance of the yellow tinge has been taken as the first landmark in the development of sex maturity, though the final criterion would, of course, be the date of first oviposition.

These experiments were started every year in April or May as soon as new stocks of locusts were available and continued till the end of the year. From May to end of August, the temperatures were uniformly high at Pasni and Ambagh, but from September onwards, there was a gradual fall in temperatures, which had the effect of prolonging the period of sex maturation and oviposition. As, under these conditions, the results

were not comparable, the summer and autumn experiments have been separately grouped together for purposes of comparison, (vide *Statements C-1 and C-2*).

As may be seen from the results tabulated under '1935—Summer Season, Pasni', there was not much difference between 'Old marrand'. 'Old marrand wetted' and 'Old marrand with moist atmosphere', and consequently in 1936 and 1937, these were dropped and a comparison was instituted only between 'Fresh marrand' and 'Old marrand'.

For purposes of comparison, the results of the experiments carried out at Pasni and Ambagh during the summer and autumn seasons of 1935, 1936 and 1937 have been tabulated under (1) the time taken for the first appearance of yellow tinge, (2) the time of first oviposition, and (3) the average number of ovipositions recorded (*vide* Table III).

In all these experiments, efforts were made to have as many duplications as possible so as to secure reliable results capable of being statistically examined, and in the case of important food plants four to nine repetitions were secured every year. Owing, however, to casualties due to various causes among the locusts introduced in the cages, and to the retarding action of low temperatures in autumn and winter, it was not found possible to get a sufficiently large number of duplications at certain parts of the year. Wherever there was a satisfactory number of duplications, the results were examined statistically and analysed, for which the writer is indebted to Dr. P. V. Sukhatme, Statistician to the Indian Council of Agricultural Research.

The results given in the table (Table III) are averages, and the differences do not, for that reason, appear in many cases to be very striking, but in many individual instances, however, they should be deemed to be markedly significant, as for instance in the case of the very short duration of sex-maturation (*viz.* 19, 20 and 21 days) recorded for *jowar*, maize and cabbage. Some general differences affecting all the experiments as a whole are also perceivable between the different years, which are presumably due to the climatic peculiarities of individual years. For instance, the year 1935 enjoyed good rainfall and the vegetation was markedly luxuriant on the reks, while 1936 had only moderate rainfall, and 1937 was actually a year of drought, so that the vegetation on the reks was more or less dry in these years, especially in 1937. Since the locusts in the cages kept in the open in the *rek* areas had been subject to the general dry conditions, and were, moreover, fed with food-plants obtainable under such conditions, it is not unlikely that the duration of the pre-oviposition period had been adversely affected and prolonged in all the different experiments.

From an examination of the data tabulated above, (Table III) it is seen that best results are obviously recorded in the summer period, though as regards the general trend the autumn experiments closely follow the summer ones except for their longer duration.

As to the different food-plants, *jowar*, *jowar* seedlings and maize have given the best results at Pasni both from the point of view of the rapidity of sex-maturation and of the number of ovipositions recorded, while fresh marrand closely follows them. *Kullichk* (*Cyperus arenarius*) gave good results at Pasni in 1935, but not in the following years. While *kharzan* and *balibur* did not show any appreciable values at Pasni, they gave excellent results at Ambagh in summer 1936 and 1937. In 1937, *Bosiri* (*Indigofera cordifolia*) and *maikh* (*Tribulus terrestris*) both preferred food-plants of the locust in the monsoon areas—were tried at Ambagh and found to give as good results as *balibur*. Cabbage was tried in two experiments at Ambagh and showed an average of 24·50 days in respect

TABLE III

Comparative statement of results of experiments on the influence of quality of food on sex-maturity of adult locusts :

Pasni : Ambagh : 1935-1937

NB.—In the Table given below 'A' stands for the Time taken for the development of yellow tinge in the wings : (in days)', & 'B' signifies 'Time taken for the first oviposition (in days)'.

S.No	Nature of Food	Time A&B	Pasni-Summer 1935		Pasni-Summer 1936		Ambagh-Summer 1936		Pasni-Summer 1937		Ambagh-Summer 1937		Pasni-Autumn 1935		Ambagh-mn-Winter 1936-37	
			A B	Av. No. of Ovipo-sitions	A B	Av. No. of Ovipo-s tions	A B	A v. No. of Ovipo-sit ions	A B	Av. No. of Ovipo-sitions	A B	Av. No. of Ovipo-sitions	A B	Av. No- of Ovipo-stioa s	A B	Av. No. of Ovipo-s ns
1.	Fresh *Marrand*	A	17.25	3.8	15.80	4.4	25·00	..	16.00	3.8	13.00	3	21.33	2	24.50	4
		B	33·50		37·00		..		45·33		37·00		59·51		79.00	
2.	Old *Marrand*	A	25·25	8	17·33	1	..	..	20.29	2.5	..	..	24	0	..	..
		B	43·10		54·50		..		53.80		..		Over 90		..	
3.	*Jowari*	A	15·25	3.62	27·00	4	..	..	32.17	3	18.00	2	13.67	2	36·00	5
		B	28.50		36.00		..		46.67		31.00		58.67		72.00	
4.	*Jowar* seedling	A	..	..	16·00	5·3	7.00	..	20.33	3	..	..	..	..	..	..
		B	..		34·33		25.00		37.40		..		..		..	
5.	Maize	A	..	..	13.00	3.75	..	..	16.75	1.7	..	..	..	..	..	..
		B	..	..	34·75		..		63.00		.		..		..	
6.	Maize seedlings	A	..	..	..	..	.	..	31.00	2.5	..	..	..	..	..	..
		B	..	..	..		..		73.50		..		..		..	

7.	Tender *Kharzan*	A	23.66	1.5	27.00	1	18.00	..	..	..	12.50	4	35.00	4	25.25	3
		B	59.50		51.00		35.00		..		33.50		72.00		76.00	
8.	Old *Kharzan*	A	..	..	..	..	1.00	..	..	..	13.00	3	..	..	..	..
		B	..		..		39.00		..		67.00		..		..	
9.	Fresh *Baliboor*	A	24.75	1	20.50	2	16.00	..	..	..	15.50	4	41.5	2	34.00	0
		B	48.33		59.00		50.00		..		37.50		104.00		..	
10.	*Kullichk*	A	21.50	2	33.25	1.6	..	..	..	..	..	..	68.00	0	..	..
		B	38.25		61.00		..		..		..		100.00		..	
11.	Mixed Food	A	..	..	..	..	..	..	21.75	1.8	..	..	..	..	..	..
		B	..		..		..		57.67		..		..		..	
12.	Cabbage	A	..	..	..	..	..	..	..	..	8.50	6	..	..	..	..
		B	..		..		..		..		24.50		..		..	
13.	Fresh 'Bosiri' (*Indigofera cordifolia*)	A	..	..	..		..		..		17.50	1	..	..	..	..
		B	..		..	..	..		..	..	37.67		..		..	
14.	Fresh 'Maikh' (*Tribulus terrestris*)	A	..	..	..	..	..	..	..	..	11.00	2	..	..	..	..
		B	..		..		..		..		36.00		..		..	

of sex maturation and 6 ovipositions, thus equalling *jowar*. In 1937, an experiment was introduced termed 'Mixed Food' in which different food-plants such as *marrand*, maize, *balibur* and *kullichk*, were given on different days of the week, but without deriving any appreciable results.

The circumstance that cereal crops like *jowar* and maize have been found to hasten the sex-maturation of adult locusts is of much significance.

STATEMENT D.

The amount (in grams.) of dried faecal matter excreted by an adult female per day on different food-plants : Pasni — 1937

Food Plant	Reference No.	Date of starting the experiment (Date of fledging)	Total period (days) for which the female remained under experiment	Average dry weight of excreta per day (gm.)	Dry weight of total excreta passed before egg-laying	Date when the experiment ended (Date of egg-laying)
1 *Fresh Marrand*	A1	7.6.37	51	0·319	16·300	28.7.37
	A5	27.6.37	40	0·248	9·920	6.8.37
	A25	11.8.37	37	0·275	10·185	18.9.37
Average	..	..	..	281	*12·135*	..
2 *Old Marrand*	A2	7.6.37	57	0·343	19·560	3.8.37
	A8	12.7.37	32	0·275	8·810	13.8.37
	A13	22.7.37	39	0·281	10·975	30.8.37
	A26	11.8.37	42	0·229	9·635	22.9.37
Average	..	..	..	0·282	*12·245*	..
3 *Jowari*	A10	12.7.37	25	0·159	5·585	16.8.37
	A21	5.8.37	71	0·104	7·400	15.10.37
Average	..	..	..	0·132	*6·492*	..
4 *Jowari Seedlings*	A16	29.7.37	56	0·114	6·390	23.9.37
Average	..	..	..	0·114	*6·390*	..
5 *Maize*	A7	11.7.37	34	0·060	2·035	14.9.37
	A15	29.7.37	49	0·073	3·565	16.9.37
Average	..	..	..	0·067	*2·815*	..
6 *Maize Seedlings*	A20	5.8.37	71	0·073	5·200	15.10.37
	A28	3.9.37	43	0·087	3·740	16.10.37
Average	..	..	..	0·080	*4·470*	..

owing to the fact that in all known cases of out-break centres found in the various parts of Mekran and Lasbela, *jowar* crops have been associated with their formation. Not only have the hoppers been found on and among such crops, but adult locusts have been observed concentrating in them for feeding and resting. Similarly in the Sind-Rajputana desert areas, where *bajri* (*Pennisetum typhoideum*) is the chief cereal crop, hoppers as well as adult locusts have been found congregating among the crops. In the absence of cultivation, wild plants like Marrand, Kharzan *Balibur*, *Indigofera cordifolia* and *Tribulus*, all of which are preferred food-plants, proved by these experiments to have a stimulating effect on the maturation of the locust, may similarly induce the formation of out-break centres in places where they occur in thick masses.

Longevity of adults

In the course of the sex-maturation experiments, it was noticed, in general, that the most suitable food quickens sexual maturity, but shortens the life-span of the individual. On the other hand, with food-plants not much liked, there seems to be a tendency to a longer lease of life specially when over-wintering is included in this period. In two instances, there were recorded at Ambagh, noteworthy cases of longevity: (1) of 306 days—in the case of a female (24-ix-36 to 27-vii-37) fed on *balibur* (*Aerua javanica*) and (2) of 290 days—in the case of another female (24-ix-36 to 11-vii-37) fed on fresh *mazoung* (*Sphaerocoma aucheri*), both of which are food plants not much preferred (*vide* Statement—C-II).

Faecal pellet experiments

As already mentioned, certain experiments were devised at Pasni to find out the relative quantity of faeces dropped by individual female locusts during the pre-oviposition period in respect of different food-plants, it being presumed that the data obtained would give a fair indication of the proportionate quantity of plant-food consumed. The first series of experiments was undertaken in 1936, when the following food-plants were tested: Fresh *marrand*, Old *marrand*, *Jowar*, maize, *balibur*, *kharzan* and *kullichk*. The cages used were, as already mentioned, hurricane lamp chimneys fitted with wire-gauze. In 1936, however, most of the locusts used for these tests succumbed to the disastrous effect of scorching land winds (the Gorich) that developed at Pasni on 21 October 1936, raising the atmospheric temperature in the screen to 107°F. In 1937, the following plants were tried:—Fresh marrand, Old marrand, Jowar, Jowar seedlings, maize and maize seedlings. The results obtained are tabulated in Statement D. Owing to the casualties caused by the dry winds, the total quantity of excreta for the pre-oviposition period could be obtained only in one case, as all the others died before laying eggs, and only the average quantity per day could be calculated. In 1937, on the other hand both data were secured. From an examination of the figures obtained, it is obvious that the data for the different plants are by no means comparable, since the volume of the excreta in the case of each food plant is determined more by the percentage of indigestible matter contained therein than by the actual quantity consumed. Plants like *marrand*, *balibur* and *kharzan* possess in addition to the water-content a great deal of roughage in the shape of spines and hairs, which being indigestible are excreted as they are and thus serve to swell the volume of the faecal matter. On the other hand, in *jowar* and maize, there is very little roughage, so that the excreta are comparatively small in quantity. It is not unlikely that both jowar and maize are, in reality, comparatively more nutritious, bulk for bulk, than *marrand*, *balibur* or *kharzan*, and this fact may account for the greater stimulating effect in regard to the sex-maturity of the locust noticed in the course of these experiments.

V. *Experiments on the influence of Quality of Food on the rapidity of growth of hoppers*

In order to determine the effect of different plant-foods on quickening post-embryonic development, various rearing experiments were undertaken at Pasni, Ambagh and Karachi in 1936 and 1937.

At Ambagh and Karachi, freshly hatched hoppers were reared individually in cages and were fed on different wild and cultivated food plants. Particular attention was paid to making a note of the number of moults undergone by each hopper and recording the duration of the various stages. No attempt, was, however, made to preserve the faecal pellets or to note the amount of plant-food consumed.

At Pasni, 30 individuals of recently hatched hoppers were kept in the chimney cages—already described—and fed on different food plants, and everyday the excreta dropped by the hoppers were carefully collected and stored in small paper packets which were kept duly labelled. Such hoppers as happened to moult were transferred to a new cage and their excreta collected separately. In the course of rearing, the general experience was that several hoppers gradually died for one reason or other, so that in certain cases only one or two reached the adult stage. The excreta gathered from day to day were duly dried in a water-oven and their weighments noted. The number of live hoppers recorded day by day was duly taken into account in working out the average weight of excreta per day per hopper in each stage.

Results obtained in regard to the duration of the hopper period as affected by the different food plants at Ambagh in 1936, 1937 and 1938, at Pasni in 1936 and 1937 and at Karachi in 1937 are shown in *Statement E.*

TABLE IV

Comparative length of the post-embryonic period as affected by different food-plants

Food Plants	Type of life history	Duration of period in days							
		Ambagh				Pasni		Karachi	
		Hotter months		Cooler months		Summer		Summer	
		5-instar.	6-instar.	5-instar.	6-instar.	5-instar.	6-instar.	5-instar.	6 instar.
Tender Kharzan	5-in.	40		63·4					
	6-in.		48		67				
Old Kharzan	5-in.	42		71·5					
	6-in.		57		76				

TABLE IV

Comparative length of the post-embryonic period as affected by different food-plants

Food Plants	Type of life history	Duration of period in days							
		Ambagh				Pasni		Karachi	
		Hotter months		Cooler months		Summer		Summer	
		5-instar	6-instar	5-instar	6-instar	5-instar	6-instar	5-instar	6-instar
Marrand Shoots	5-in.	40		61·7		42·[illegible]			
	6-in.		61·3		76·7		50·9		
Old *Marrand*	5-in.					52			
	6-in.						56		
Jowari Seedlings	5-in.	35·9		52·3		..			
	6-in.		44·8		64·7		49		
Jowari	5-in.					..			
	6-in.						67		
Balibur	5-in.	45·6		..					
	6-in.		..		84·2				
Mazoung Shoots	5-in.			92·2					
	6-in.		..		96				
Kohl Rabi Cabbage	5-in.	31		48				39	
	6-in.		..		..				49·5
'*Bosiri*'	5-in.	36							
	6-in.		40						
'*Maikh*' (*Tribulus*)	5-in.	37		..					
	6-in.		..		77·7				
'*Palak*'	5-in.			109				45.2	
	6-in.				133				55
'*Isepphal*'	5-in.	38·7		38·7					
	6-in.		..		..				
'*Dranna*'	5-in.	44·5		..					
	6-in.		..		45·3				
'*Kullichk*'	5-in.					..			
	6-in.						81		
Maize	5-in.					57			
	6-in.						73		
Maize seedlings	5-in.					44			
	6-in.						73·5		

STATMENT P

The amount (in grams) of dried faecal matter excreted per hopper per day in different stages for different food plants, Pasni—1937

Food Plant	Reference No.	Date of starting experiment	Average of dry weight (in grams.) of faecal matter excreted per hopper per day in each stage										Total length of hopper period	Date when experiment ended	Remarks
			I stage		II stage		III stage		IV stage		V stage				
			No. of hoppers	Weight of faeces per hopper	No. of hoppers	Weight of faeces per hopper	No. of hoppers	Weight of faeces per hopper	No. of hoppers	Weight of faeces per hopper	No. of hoppers	Weight of faeces per hopper			
Fresh Marrand	W1 W6 W11	26-4-37 5-6-37 20-6-37	28-20 24-3 30-16	0·0052 0·0050 0·0061	20-18 3 16-8	0·0153 0·0167 0·0155	18-12 3-2 8-6	0·0548 0·0480 0·0512	12 2 6	0·1667 0·1193 0·1233	12 2 6	0·2381 0·2281 0·2001	[illegible] 4 [illegible] 3 5	[illegible]-6-37 21-7-37 4-8-37	1 extra moult.
Average	..	...	..	0·0054	...	0·0158	..	0·0513	..	0·1364	...	0·2221	37-46	...	
Old Marrand	W2 W5 W12	26-4-37 7-6-37 21-6-37	28-9 26-16 20-14	0·0069 0·0071 0·0073	9 16-13 14-8	0·0186 0·0166 0·0185	9-6 13-10 8	0·0648 0·0549 0·0680	5 10-8 8-6	0·1468 0·1122 0·1312	5 8 8	0·2479 0·2351 0·2099	37-43 43-46 45-48	8-6-37 23-7-37 8-8-37	1 extra moult in some hoppers.
Average	...	..	..	0·0071	...	0·0179	..	0.0626	...	0·1301	..	0.2310	37-48	..	
Maize	W3 W16	26-4-37 5-7-37	28-19 22-16	0·0023 0·0029	19-16 16-5	0·0068 0·0040	16-11 5-2	0·0233 0·0180	11-6 2	0·0451 0·0309	6-2 2	0·0554 0·0603	58-62 78-79	27-6-37 22-9-37	1 extra moult in all
Average	..	..	..	0·0026	..	0·0054	..	0·0206	...	0·0380	..	0·0578	58-79	..	
Maize seedings	W4 W10 W13	19-5-37 17-6-37 26-6-37	32-7 22-7 26-9	0·0024 0·0028 0·0027	7-4 (After 9-8	0·0064 first 0·0047	4-2 stage 8-4	0·0186 hoppers 0·0156	2-1 1	0·0369 (escaped.) 0·0234	1 Moulted	0·0266 into adult	75	21-7-37 8-9-37	1 extra moult. Only 1 hopper remained in the end and it directly moulted into adult after 4 th stage.
	W19 W20	16-8-37 23-8-37	28-2 20-3	0·0010 0·0015	(Hoppers 3	died 0·0067	in 3	mass on 0·0173	17-8-37 3	0·0415	2	0·0975	73-74	20-8-37 5-11-37	1 extra moult in all
Average	..	..	..	0·0021	...	0·0059	..	0·0172	..	0·0339	..	0·0620	73-75	..	
Jawari	W9	14-6-37	32-2	0·0025	...	..	..	..	...	..	..	...	..	2-7-37	All hoppers died in 2nd stage.
Plant	W14 W18 W21	27-6-37 3-8-37 23-8-37	22-1 44-5 20-4	0·0047 0·0021 0·0019	... 5-4 3	.. 0·0051 0·0055	... 4-3 3	.. 0·0134 0.0184	.. 3-1 2	.. 0·0377 0·0423	.. 1 2	... 0·0650 0·0784	.. 78 61-63	9-7-37 20-10-37 25-10-37	1 extra moult in all 1 extra moult in all
Average	...	..	...	0·0028	..	0·0053	..	0·0159	...	0·0400	...	0·0717	..	..	
Jowari seedlings	W5 W7 W15 W17	23-5-37 5-6-37 2-7-37 11-7-3	22-7 24-2 32-10 32-7	0·0020 0·0021 0·0032 0·0023	7-3 ... 10-4 7-6	00·051 .. 0·0035 0·0035	3-1 .. .. 6 4	0·0113 ... ... 0·0242	1 4-3	0·0575 .. .. 0·0	1 3	0·1305 .. .. 0·1120	54 43-47	15-7-37 16-6-37 20-7-37 27-8-37	1 extra moult. 1 extra moult in most of the hoppers.
Average	..	..	..	0·0024	...	0·0057	..	0 0177	...	0·06	..	0·1212	..	..	

In evaluating the influence of the different food plants in quickening the development of hoppers, it was found necessary to make some allowance for the effect of climatic conditions on the duration of the hopper period, and also for the additional time taken for reaching the adult stage whenever an extra moult occurred. In presenting an analysis of the results, therefore, they have been separated into (1) Summer or hot season and (2) Autumn-Spring or cool season data. In addition, these have all been arranged under 5-instar and 6-instar type of life-history so as to make the various items fully comparable.

For facilitating comparison, data on the average duration of the hopper period noted for each different food-plant have been arranged according to the type of life-history and the season in Table IV.

From the results tabulated (Table IV), it is seen that the food-plants experimented with may be placed in the following order of merit in regard to their effect on shortening the developmental period of the hoppers:—

Cabbage-*Kohl-rabi*, *jowar* seedlings, *bosiri* (*Indigofera cordifolia*) *maikh* (*Tribulus terrestris*), *ispe-phul* (*Convolvulus pleuricollis*), fresh *marrand*, and tender *Kharzan* (31 to 40 days). Then come maize seedlings '*dranna*' (*Crotalaria burhia*) and '*balibur*' (*Aerua javanica*)—(42 to 45 days). Leaves of mature *jowar* and maize were evidently not liked by hoppers.

Faecal pellet experiments. At Pasni, the excreta of hoppers under rearing were collected throughout the hopper period, and calculations were made as to the average quantity excreted per hopper per day during each instar. The results obtained in 1937 are presented in Statement F.

For facilitating a general comparison of all the results, Table V has been prepared showing the results obtained in 1936 and 1937 under various items, such as sex maturation, the growth of hoppers and the quantity of excreta passed by adults and hoppers, in the 'quality of food' experiments carried out at Pasni. Data in regard to the average water-content of various food-plants used in these experiments are also included therein. (*See Table V*).

In 1936, most of the young hoppers fed on *jowar*, *balibur* and *kharzan* failed to grow. In 1937, experiments with balibur and kharzan were not repeated but those fed on *jowar* and *jowar* seedlings throve well and reached the adult stage. In 1936, moreover, several of the hoppers under experiment fell victims to the scorching '*Gorich*' wind that prevailed on the 21 October, 1936, so that some of the experiments were prematurely cut short.

From a study of the data on the relative quantity of excreta recorded for each larval instar in the case of the different food plants, the following observations may be made. (1) The average amounts of excreta for Fresh or Old *marrand* are approximately 2 to 3 times as great as those for *jowar* or *jowar* seedlings, and about 3 to 4 times as great as those for maize or maize seedlings. The quantity of excreta for *kullichk* is on the other hand, only slightly less than that for *marrand*. As already explained in a previous para in connection with similar data for sex maturation experiments, the relative quantities of faecal matter recorded for the different food-plants do not have any reference to the volume of plant-food consumed, but are apparently due to the different percentages

TABLE V

Averages for sex-maturation period of females, duration of hopper period, dry weight of faecal matter excreted by an individual female and hopper in different stages and water-content of the various food-plants used in these experiments

PASNI

1936

Item	Name of Food-plant	Fresh *Marrand*	Old *Marrand*	*Jowar*	*Jowar* Seedlings	Maize	Maize Seedlings	*Balibur*	*Kullichk*	*Kharsan*
A. Sexual maturation period of female (in days.)	Time taken for the 1st appearance of yellow in hind wings (days)	16	17·2	27		13		20·5	33·2	27
	Time taken for the 1st egg-laying (days)	27	Over 54	36		35		63	64	51
B. Duration of hopper period	(in days) 5-ins. type	46	50			52			81 7-instar	
	6-ins. type	53	56			63				
C. Amount of dry faecal matter passed by a female per day.	Average dry faecal matter (in grams) per day.	0·212	0·258	0·122		0·113		0·237	0·159	0·194
D. Dry weight of faeces per hopper per day in various stages (in grams)	1st—instar	0·0063	0·0077	0·0008		0·0019		0·0047	0·0022	0·0027
	2nd—instar	0·0153	0·0174	0·0055		0·0072		0·0056	0·0078	0·0105
	3rd—instar	0·0486	0·0519	..		0·0177		..	0·0275	..
	4th—instar	0·0994	0·1226	..		0·0443		..	0·0764	..
	5th—instar	0·1700	0·1897	..		0·0627		..	0·1434	..

1937

Item	Name of Food-plant	Fresh *Marrand*	Old *Marrand*	*Jowar*	*Jowar* Seedlings	Maize	Maize Seedlings	*Balibur*	*Kullichk*	*Kharsan*
A. Sexual maturation period of female (in days).	Time taken for the Ist appearance of yellow in hind-wings (days).	16	20	32	30	17	31			
	Time taken for the 1st egg-laying (days).	45	65	46	42	64	78			
B. Duration of hopper period.	(in days) 5-ins. type	41	37—40	..	45	60	..			
	(in days) 6-ins. type	45	45	62·78	54	78	74			
C. Amount of dry faecal matter passed by a female per day.	Average dry faecal matter (in grams) per day.	0·281	0·282	0·132	0·114	0·067	0·080			
D. Dry weight of faeces per hopper per day in various stages (in grams).	1st—instar	0·0054	0·0071	0·0028	0·0024	0·0026	0·0021			
	2nd—instar	0·0158	0·0179	0·0053	0·0057	0·0054	0·0059			
	3rd—instar	0·0513	0·0626	0·0159	0·0177	0·0206	0·0172			
	4th—instar	0·1364	0·1301	0·0400	0·0619	0·0380	0·0339			
	5th—instar	0·2221	0·2310	0·0717	0·1212	0·0570	0·0620			
E. Water content of plants (percentage).	Percentage of moisture in various plants.	84·80	78·27	76·36	80·29	84·95	87·70	70·91	78·13	75·38

of roughage contained by the individual plants. In spite of the high water-content, marrand possesses a fairly large percentage of spines and hairs, whereas maize—the water content of which is equally high—has no roughage, which explains the considerable differences in the amounts of excreta recorded. (2) It is also seen that these differences in the quantity of faecal matter between plant and plant are maintained at all stages of the hopper period. (3) The figures of average weight of excreta for the same plant for successive instars also roughly indicate a proportionate increase from one instar to the next—quite comparable to the degree of increment in weight and size of successive hopper stages, the rate of increase being generally two- to three-fold between successive instars.

Some general observations on the experiments on quality of food

Although the experiments carried out under the present scheme were admittedly not very exhaustive, it may be claimed that they have given a fairly definite indication as to the importance of the quality of food in causing an acceleration of the sexual maturation of young adults and of the growth of the hoppers. Since it is now generally conceded that the development of an outbreak centre is almost always due to the rapid development of two generations in quick succession in the outbreak area, any factor that might contribute to the speeding up of the breeding would be of the utmost import in this connection, and there is little doubt that the presence of food plants capable of stimulating the rapid growth of hoppers and of hastening the maturity of young adults would play an important part in the causation of incipient swarming.

Kennedy (1939), who has carried out intensive ecological studies in an outbreak area at Hamashiameb on the Red Sea coast of Sudan, is, however, not inclined to allocate to the food factor anything but a subsidiary role. While conceding that growth-stimulating foods such as *Heliotropium undulatum*, might accelerate 'Real Concentration', since the more mobile later instars would thereby be reached sooner, and also that growth-stimulation might assist in 'Virtual Concentration' as a result of rapid breeding, he believes that this would only contribute to the fitting in of a second generation into a winter season. He further says (p. 444) that the effect of food on the rate of sexual maturation can only influence prospects of a second winter generation and hence of 'Virtual Concentration', probably having no influence on the concentration of the first winter generation.

In the Mekran area of the Indian region, where spring breeding usually occurs, locusts are found over-wintering in the coastal areas and the earliest breeding also occurs there. As the spring advances, locusts migrate into the interior valleys of Mekran from the coast and may breed there if conditions are favourable during the months April, May and June. Adults of the new generation begin to appear on the coastal areas early in April and usually migrate into the hinterland more or less immediately. As the interior of Mekran is mostly hilly and stony and patches of natural vegetation as well as of cultivation are restricted to loamy-soils at the bottom of the valleys, migrating locusts usually become concentrated on such patches (Real Concentration). Summer cultivation is mostly confined to the *jowar* crop, and various wild plants such as species of *Astragalus*, *Trigonella*, *Tephrosia*, *Tribulus*, *Chrozophora* and *Heliotropium*, as well as the Camel-thorn (*Alhagi camelorum*) all of which are plants relished by locust adults and hoppers and commonly found round about cultivation either as weeds or natural vegetation.

Locusts concentrated on the *jowar* crop may be expected to attain sexual maturity very early, and lay eggs in the neighbourhood, and the hoppers on hatching would find a fair amount of growth-stimulating food. As temperatures are fairly high in late spring, breeding would be fairly rapid and conditions should apparently be quite favourable for the development of incipient swarms. Although no actual observations have been made in the interior of Mekran in this matter, there is little doubt that the food factor is fairly important, since several outbreak centres are known to have developed under such conditions in the interior of Mekran.

As to the adults of the over-wintered brood, it is now fairly well established that the locusts found in the winter months in the Mekran coastal areas are mostly migrants from summer brood areas in the Sind-Rajputana desert. On the coastal reks the vegetation is generally very much dried up at the end of autumn, and one might imagine that locusts may not find any green plants for feeding owing to the prevalent drought, but as a matter of fact, with the setting in of the moist western wind at the end of autumn, most of the perennial vegetation on the reks, such as *marrand* and *mazoung*, have been noticed putting forth fresh shoots in spite of the absence of rainfall, and tender shoots of preferred food-plants like *marrand* may be expected to stimulate sexual maturation even before the occurrence of the winter rains. On the other hand, with the commencement of rainfall, various annuals spring up on the reks and furnish food capable of quickening sex maturity among the over-wintered adults, though there is not much likelihood of any concentration being caused under the conditions prevalent at this period on the coastal areas.

In addition to the natural vegetation, young *rabi* crops, such as wheat, barley and rape, raised in parts of Mekran would also provide food capable of stimulating maturity, in case locusts happen to be present in the neighbourhood.

VI. Food Preferences of the Desert Locust

The natural haunts of the desert locust are mostly to be found in fairly open sandy areas more or less densely covered by stunted scrub vegetation. The low scrub not only affords the locust shelter from the rigours of the climate and protection from enemies, but also forms the main source from which its requirements of food and water are met. The desert vegetation is composed partly of perennial plants which derive their water supply from the deeper layers of the soil and continue to live throughout the year, and partly of annuals which spring up in fair numbers after rainfall and die down when the rains are over.

Much information is on record regarding the plants—cultivated or wild—devoured by the swarms of the desert locust in the various countries subject to its invasions, which serves to indicate that it is fairly cosmopolitan in its tastes and attacks a great variety of plants. Very little was, however, known about the feeding habits of the solitary phase of the locust till investigations were started in various parts of the area of its habitat during the last decade. In the course of survey work, extensive observations were made on the food-plants on which the solitary phase individuals subsisted in the various breeding areas in north-west India, and they appeared to indicate that the phenomenon of phase transformation might possibly be intimately connected with the peculiarities of distribution of the preferred food-plants, as they might lead to local concentrations of locusts wherever they were in abundance. A critical

examination of the various food-plants was, therefore, made in the different areas of breeding especially to note relative preferences exhibited by the locust, if any, in nature.

Records of food preferences in respect of the Gregaria phase

Künckel d'Herculais (1893-1905) has given a long list of plants eaten or rejected by the desert locust in Algeria. Plants eaten include maize, *Plantago, Calligonum, Cynodon dactylon, Andropogon spp.*, the wild Jujube—*Zizyphus lotus*, etc. Among plants refused were species of *Anabasis. Suaeda, Artemisia and Ephedra and Peganum harmala.*

Mann and Burns (1931) have recorded that almost all crops in Sind and Kathiawar were damaged:—wheat, rapeseed, *jowar*, cotton, castor, *jambo* (Brassica), gram and vetch, as well as mango blossom. The following plants were also eaten: *Capparis aphulla, Salvadora* sp., Casurina, *Thespesia populnea, Terminalia catappa, Poinciana regia, Millingtonia, Ficus indica* and *F. religiosa*, Jasmine, Bougainvillea, and *Murraya koenigii.* The following plants were not attacked:—*Acacia arabica, Prosopis spicigera, Tamarisk, Melia azadirachta, Nerium odorum, Tecoma stans, Calotropis gigantea, Ipomoea pescapra, Solanum nigrum* and coconut (lightly attacked).

Williams (1933) recorded the following as regularly eaten in east Africa: *Tecoma stans*, papaya, erythrina, casuarina, grevillea, cabbage, cassawa (very severe damage), maize, okra, mulberry, coconut, peas, peach, citrus, egg-plant and lantana. The following were not eaten: Mango, oleander, pumpkin, castor, Loquat, Litchi, tea, *Pandanus, Cassia fistula, Ficus retusa, Eugenia jambos* and *E. jambolana, Pennisetum purpureum*, etc. The hoppers were not found attacking *Aerua tomentosa, Achyranthes aspera, Trianthema pentandra, Solanum indicum*, etc. but were found partial to *Cynodon* and *Eragrostis.*

Ballard and his co-workers (1932) found fig trees badly damaged in Egypt, as also the following wild plants: *Chrozophora plicata, Calligonum comosum, Aerua tomentosa, Capparis spinosa, Acacia seyal, Alhagi maurorum, Lycium europaeum, Citrullus colocynthis, Cynodon dactylon, Imperata cylindrica, Rumex vesicarius, Astragalus* spp., *Artemisia* sp.

Predtechensky (1935) compiling the data of various Russian workers, gives the following information in regard to the plant preferences of the *gregaria* phase of the locust in Turkmenistan: Among cultivated plants, cotton, sesamum, cabbage, maize, tomato, onions, peas, and water melon; among trees poplars and *Eleagnus hortensis*, and tamarisk was also attacked to a certain extent: among the wild vegetation, *Alhagi camelorum, Phragmites communis, Lycium, Convolvwlus erinaceus, Peganum harmala, Cyperus rotundus, Cynodon dactylon, Portulaca oleracea, Xanthium strumarium, Cucumis trigonus, Solanum nigrum, Calligonum setosum, Chrozophora sabulosum* (much preferred), *Salsola arbuscula. S. kali, Sophora* sp., etc. *Artemisia maritima* was only slightly attacked. Hoppers preferred *Alhagi camelorum* and *Salsola kali*, but avoided *Salsola sclerantha* and *Sophora pachycarpa.* Pink locusts are reported to have avoided *Peganum harmala, Salsola sclerantha, Sophora pachycarpa* and *Tamarix* at certain places, and to have shown a preference for *Salsola kali* as against *Alhagi camelorum* at other places. Hoppers of the solitary phase were found by Prutensky mostly on *Amaranthus angustifolium*, and less frequently on leaves of melon and water-melon, and on various weeds such as *Kochia hyssopifalia, Solanum nigrum, Alhagi camelorum, Salsola kali* etc.

Food plants of the Solitary phase in India

The following plants have been found to be associated with the breeding of the solitary phase of the locust: *Heliotropium undulatum* (*Marrand*) *H. eichwaldi* (*Popat*), *Aerua tomentosa* (*javanica*)—(*Booh or Balibur*), *Chrozophora verbascifolia* (*Popat* or *Kapocham*), *Sericostoma pauciflorum* (*Kharzan*), *Tribulus terrestris* (*Sareng, Maikh or Trikandi*), *Indigofera cordifolia* (*Wekra, Bekkar* or *Bosir*), *Tephrosia hookeriana* (*Matkinuk, Maso or Bishani*), *Cenchrus biflorus* (*catharticus*)—(*Bharut*) and *Crotalaria albida* (*Tambol*). In addition, green hoppers have on occasions been found also on the following plants in the different areas: *Alhagi camelorum* (*Shinz* or *Kanderi*), *Cyperus arenarius* (*Kullichk* or *Luchabri*), *Cenchrus ciliaris* (*Sibar*), *Convolvulus pleuricollis* (*Ispe-phul*) *Dipterygium glaucum* (*Phel*), *Zizyphus nummularia* (*Bordi*), *Lycium europeum* (*Murali*), *Dactyloctenium scindicum* (*Gandhil*), *Trigonella corniculata* (*Shimsh*), etc. Green hoppers have also been found on cultivated plants such as *bajri* (*Pennisetum typhoideum*), *jowar* (Sorghum), *Guar* (*Cyamopsis psoralioides*), *moth* (*Phaseolus aconitifolius*), *til* (*Sesamum indicum*) and water-melon (*Citrullus vulgaris*).

Maxwell-Darling (1934) records the following as the natural food-plants in the Kordofan area of Sudan: *Chrozophora oblongifolia, Melhania denhamii,* and *Crotalaria thebaica.* On the Red Sea coast the main food-plant was *Heliotropium undulatum.*

Food preference experiments (1932). [Observer: Dr. K. R. Karandikar]

The earliest experiments on food preference were carried out at Pasni in 1932, in which adults as well as hoppers were subjected to feeding tests with some of the wild plants found on the Pasni Rek areas.

Adults. A single adult was confined in a small cage and provided with a measured quantity of food plant. At the same time an equal quantity by weight was kept separate as control to determine the loss of weight due to evaporation. At the end of 24 or 36 hours, the quantity of food-plant left over after feeding was weighed, as also the control lot. From the data thus obtained, the total amount of fresh plant-food consumed by the locust during the experiment was determined, and in order to facilitate comparison, the results were expressed in terms of the percentage of the body-weight of the locust used for the experiment. The full data are given in *Table VI.* Out of 14 plants tested, five were positively rejected: *Gaz* (*Tamarix dioica*), *Sorichk* (*Atriplex crassi folia*), *Jaur* (*Nerium odorum*), *Kharagh* (*Calotropis procera*), and *Porant* (*Cornulaca monacantha*). The other plants—arranged in the order of the preference values determined in these experiments—are the following:—*Marrand* (*Heliotropium undulatum*), *Ipomoea biloba, reghit* (*Suaeda fruticosa*), *shinz* (*Alhagi camelorum*), *mazoung* (*Sphaerocoma, aucheri*), *shalwardir* (*Asparagus curillus*), *balibur* (*Aerua javanica*), *shimil* (*Indigofera paucifolia*), and *Jaduk* (*Lycium europeum*).

Hoppers. Experiments were also similarly carried out to find out the food preferences of the hoppers in regard to some of the dominant plants on the Pasni reks. About 20 hoppers mainly of the I and II instars were kept in each cage and supplied with a certain weighed quantity of the food plant once in 12 hours, keeping an equal quantity of the plant as control to determine the rate of driage. Weighments of the food remnants found at the end of 12 hours and of the control were made for calculating the exact quantity taken by the hoppers. The results were expressed in the form of a percentage of the amount of food taken by each hopper in terms of its mean body weight. The food preference values

TABLE VI

Results of food experiments with adult locusts on the Pasni reks

(Dr. K. R. Karandikar—1932)

(In grms.)

*Order of preference	Duration of experiment in hours	Weight of control		Weight of experimental food at end of experiment	Weight of food consumed during experiment	Weight of food consumed after calculating for driage	Mean weight of food taken during experiment	Mean weight of food eaten in 24 hours	Mean weight of locust	Percentage of food weight to weight of locust
		at beginning of experiment	at end of experiment							
I	36	105	38.176	36.199	1.977	7.574	4.775	3.183	2.210	143
II	24	40	36.662	35.355	1.307	1.411	1.361	1.361	2.462	55
III	36	60	52.656	51.020	1.636	1.920	1.778	1.185	2.210	53
IV	24	30	21.545	20.733	.812	1.163	.987	.987	2.700	36
V	36	60	53.159	52.440	.719	.840	.765	.710	2.210	32
VI	24	15	12.905	12.410	.495	.601	.548	.548	2.235	24
VII	24	40	28.538	28.252	.286	.409	.347	.347	2.361	14
VIII	24	30	10.585	10.552	.033	.093	.063	.063	13.3	4
IX	24	40	33.644	33.607	.037	.044	.04	.04	1.824	2

*The names of plants concerned are given in the text.

obtained are given below arranged in the order of their merit. The water contents of the different plants are also included, and it is seen from an examination of the results that the amount of water content does not always connote a higher preference value.

TABLE VII

No.	Name of Plant	Water Content (per cent)	Percentage of food quantity to weight of hopper
1	Marrand (*Heliotropium undulatum*)	84·5	361
2	Gandhil (*Eleusine flagellifera*)	61·5	266
3	Sibar (*Cenchrus ciliaris*)	69·75	205
4	Shalwardir (*Asparagus curillus*)	59·5	170
5	Shinz (*Alhagi camelorum*)	71·9	159
6	Kahurbahar (*Tribulus terrestris*)	69·3	154
7	Mazung (*Sphaerocoma aucheri*)	75·2	122
8	Gaz (*Tamarix dioica*)	59·2	113
9	Reghit (*Suaeda fruticosa*)	75·1	111
10	Kullichk (*Cyperus arenarius*)	79·9	110
11	Droog (*Eragrostis cynosuroides*)	69·9	64
12	Jaduk (*Lycium europaeum*)	74·1	49

Experimental observations were also made on the quantity of food eaten by hoppers in the different stages—the plant-food used being marrand (*Heliotropium undulatum*).

TABLE VIII

Stage of hopper	Average weight of food eaten per day in grms.	Average weight of hopper in grms.	Weight of food per day in terms of weight of hopper
First Instar	0·084	0·027	Over 3 times
Second Instar	0·158	0·068	Over 2 times
Third Instar	0·387	0·188	Over 2 times
Fourth Instar	0·636	0·401	Over 1½ times
Fifth Instar	1·524	1·027	About 1½ times

Food preference experiments—1936 to 1938

After 1932, further experiments were not undertaken till 1936, in which year Dr. M. L. Roonwal carried out a series of trials with various common food-plants at Pasni, and continued them on a more elaborate scale in 1937, with the aim of working out of a scale of food preference values for a large number of plants found on the coastal areas of Mekran.

Similarly, Mr. D. R. Bhatia carried out various observations and experiments in 1936 for plants common in the Sind-Rajputana desert areas, and in 1938, Mr. R. N. Batra carried out a series of trials with a few plants common in the Ambagh area.

Pasni Experiments of 1936-1937—[Observer: Dr. Roonwal.]

Roonwal evolved the following technique in determining the food preferences of the locust in the Pasni area. Adult locusts were also used in some of the experiments, but in the main blackish or brown hoppers bred in cages under fairly crowded conditions were used in these tests. Cages, 3 ft. square and 3 ft. high, with wire-gauze sides and plank-bottoms were employed in the earlier trials, but utlimately smaller cages

STATEMENT G.

Food Preference Values (P. V.) of the more common plants—cultivated or wild—found in the neighbourhood of Pasni, in relation to the cage-bred hoppers (mostly III—V stages) of the desert locust
(Dr. M. L. Roonwal)

S. No.	Common name of plant	Scientific name	Natural order	Abbreviation	P. V. from different sets	Average P.V.
1	Abdar-kah	*Andropoghon annulatus*	Gramineae	A.	94 (set 16)	94
2	Arjun (plant)	*Panicum miliaceum*	do.	ar.	42 (set 28)	42
3	Arjun (seedling)	*Panicum miliaceum*	do.	ars.	46 (set 26)	46
4	Aputag	*Boucerosia aucheriana*	Asclepiadaceae	At.	0 (set 20)	0
5	Baliboor	*Aerua javanica*	Amarantaceae	B.	7 (set 1)	7
6	Bajra (plant)	*Pennisetum typhoideum*	Gramineae	b.	151 (set 2)	51
7	Bajra (seedling)	*Pennisetum typhoideum*	do.	bs.	187 (set 13)	87
8	Babbur (garden plant)	*Parkinsonia aculeata*	Leguminosae	Ba.	58 (set 25)	58
9	Barshonk	*Panicum turgidum*	Gramineae	Bk.	43 (set a)	43
10	Droog	*Eragrostis cynosuroides*	do.	D.	14 (set 16)	14
11	Dedhar	*Euphorbia neriifolia*	Euphorbiaceae	d.	3 (set 20)	3
12	Gaz	*Tamarix gallica*	Tamaricaceae	G.	0 (set 7)	0
13	Gandil	*Dactyloctenium scindicum* (*Eleusine aristata*)	Gramineae	g.	71 (set 12)	71
14	Gandam (Galla or wheat) (plant)	*Triticum vulgare*	do.	Ga	402 (set 32)	402
15	Gandam (seedling)	Do.	do.	Gas.	87 (set 27)	87
16	Gishtar	*Periploca aphylla*	Asclepiadaceae	Gi.	5(set 21)	5
17	Gunj	*Citrullus colocynthis*	Cucurbitaceae	Gj.	77 (set 18)	77
18	Gandako	*Peganum harmala*	Rutaceae	Gk.	23 (set 18)	23
19	Gomaz	*Panicum antidotale*	Gramineae	Gz.	91 (set 17)	91
20	Harchad	*Aeluropus villosus*	do.	H.	77(set 16)	77
21	Jawari (plant)	*Andropoghon sorghum*	do.	J.	66 (set 1) +24 (set 5) +62 (set 15)	53
22	Jawari (seedling)	*Andropoghon sorghum*	do.	Js.	56 (set 14)	56
23	Jhawad	*Cornulaca monacantha*	Chenopodiaceae	Jd.	42 (set 23)	42
24	Jhaduk	*Lycium barbarum*	Solanaceae	Jh.	10 (set 7)	10
25	Jugr	*Prunus eburnea*	Rosaceae	Ju.	15 (set 24)	15
26	Kullichk	*Cyperus arenarius*	Cyperaceae	K.	93 (set 1) +111 (set 3) +79 (set 4)	94
27	Kharzan or Madgikah	*Sericostoma pauciflorum*	Boraginaceae	k.	15 (set 1) +65 (set 23)	40

STATEMENT G.—*contd.*

***Food Preference Values** (P. V.) of the more common plants—cultivated or wild—found in the neighbourhood of Pasni, in relation to the cage-bred hoppers (mostly III—V stages) of the desert locust*

(Dr. M. L. Roonwal)

S. No.	Common name of plant	Scientific name	Natural order	Abbreviation	P. V. from different sets	Average P. V.
28	Karag (or Ak)	*Calotropis gigantea*	Asclepiadaceae	Kg.	0 (set 20)	0
29	Kahur	*Prosopis spicigera*	Leguminosae	kr.	13 (set 11)	13
30	Kash	*Saccharum griffithii*	Gramineae	Ks.	16 (set 17)	16
31	Limmar	*Heleochloa dura*	—do—	L.	16 (set 11)	16
32	Layyo	*Cressa cretica*	Convolvulaceae	l.	1 (set 12)	1
33	Lantu	*Taverniera nummularia*	Leguminosae	La.	63 (set 22)	63
34	Lucerne (cultivated plant)	*Medicago sativa*	—do—	Lu.	97 (set 19)	97
35	Marrand	*Heliotropium undulatum*	Boraginaceae	M.	100 (Taken as standard).	100 (Stan.)
36	Mazung	*Sphaerocoma aucheri*	Caryophyllaceae	m.	5 (set 1) +4 (set 3) +10 (set 7) +16 (set 8)	8
37	Mash or Moong (plant)	*Phaseolus radiatus*	Leguminosae	ma.	127 (set 28)	127
38	Mash or Moong (seedling)	—do—	—do—	mas.	84 (set 27)	84
39	Mach (Date palm)	*Phoenix dactylifera*	Palmae	mc.	9 (set 16)	9
40	Mond	*Sporobolus arabicus (indicus ?)*	Gramineae	md.	27 (set 11)	27
41	Maize (plant)	*Zea mays*	—do—	Mz.	144 (set 1) +130 (set 2)	137
42	Maize (seedling)	*Zea mays*	—do—	Mzs.	29 (set 29)	29
43	Nadag	*Andropoghon jwarancusa*	—do—	N.	76 (set 17)	76
44	Peesh	*Nannorrhops ritchieana*	Palmae	P,	23 (set 21)	23
45	Reghit	*Suaeda fruticosa*	Chenopodiaceae	R,	3 (set 9)	3
46	Shalvardir	*Asparagus curillus*	Liliaceae	S.	0 (set 7) +1 (set 8)	1
47	Sirish (or Neem)	*Azadirachta indica*	Meliaceae	Si.	0 (set 25)	0
48	Shanikush	*Lotus stocksii*	Leguminosae	sk.	45 (set 7) +36 (set 10)	41
49	Shirwal	*Convolvulus beluchistanensis*	Convolvulaceae	Sl.	31 (set 12)	31
50	Shimil (Chil, Jhil)	*Indigofera paucifolia*	Leguminosae	Sm.	9 (set 9) +10 (set 12)	10
51	Sorichk	*Atriplex crassifolia*	Chenopodiaceae	So.	3 (set 21)	3
52	Sibar	*Cenchrus ciliaris*	Gramineae	Sr.	97 (set 17)	97
53	Tambol	*Crotalaria albida*	Leguminosae	T.	7 (set 7) +36 (set 10) +24 (set 8)	22

square and 15 in. high were adopted, as they were more handy and the hoppers showed a better response therein. Hoppers were kept without food for at least six hours prior to the experiment. Small branches or twigs with fresh leaves of the different plants to be tested—usually four or five at a time—were kept in small glass dishes with water on the floor of the cage. In the experiments carried out in 1937, the glass dishes were replaced by shallow wire-gauze receptacles—2 in. high and 2 in. in diameter—containing moist sand, in which the twigs were stuck in, as the hoppers found less difficulty in reaching the food-plants than in the case of the slippery sides of the glass receptacles. Generally, forty hoppers of second to fifth stages were kept in each of the experimental cages. After introducing the food-plants, the hoppers were slightly disturbed so as to rouse them into immediate activity after which they were left alone for about fifteen minutes. By this time, the hoppers were usually found to have settled down to food, and notes were taken of the number of hoppers observed on each food-plant. After a time the food-plants were removed, and after a subsequent interval of six hours of starvation, the trials were repeated the plants being arranged in different relative positions, so as to eliminate accidental errors such as those due to incidents of lighting, wind direction and similar factors. Each set of experiments was repeated 6 to 16 times, and the relative preference to the different plants determined by taking into consideration the total number of hoppers recorded on each plant. Roonwal experimented with nearly 50 different plants obtainable at Pasni, and in order to arrive at comparable results, he hit upon the idea of evolving a scale of Preference Values—(P.V.) of the different plants by working out the percentages with marrand as the standard, the values having reference only to the particular phase and stage of the locust experimented with. The following is given as an example of how the Preference Values were worked out.

SET—17

Plants	Gz. (Gomaz)	Sr. (Sibar)	Ks. (Kash)	N. (Nadag)	M. (Marrand)
Actual counts	64	68	11	53	70
Preference values (in percentages)	91	97	16	76	100 (Standard)

He worked out the final scale by combining together the results of the different sets of experiments by calculating the averages of the preference values. In cases where marrand had not been employed in any particular set, any plant employed in the experiment whose preference value with reference to marrand had been found out was taken as the standard, and the actual value was worked out for inclusion in the general scale.

Statement G gives the list of Preference Value as worked out in 1937 and serves to give at a glance the relative values of different plants in the Pasni area from the point of view of locust feeding.

It is seen, however, that *balibur* and *kharzan*—both of which are known to be relished by hoppers at Ambagh and in the Sind-Rajputana area—have been found at Pasni to have low preference values, while *gunj* (*Citrulus colocynthis*), which has been found elsewhere to be one

of the plants refused by hoppers, is seen to have a fairly high value. It is possible that this may be due to differences in the growth of the plants owing to climatic and other conditions. In future experiments, it would be advisable to include *marrand* in all sets of experiments as it is taken as the standard, and to have a larger duplication of the sets to get decisive values.

Experiments with adults. In the case of adults, experimentation was only with *jowar* and *marrand* in 1936 and 1937, and the adults showed twice as much preference for *jowar* as for *marrand.* The hoppers, on the other hand, have indicated very little preference for *jowar* compared with *marrand.*

2. *Food preference experiments at Chachro in* 1936—[*Observer Mr. D. R. Bhatia*]. Bhatia (1940) carried out several experimental observations at Chachro in August and October 1936 to find the order of preference exhibited by hoppers in regard to various plants—cultivated and wild—commonly met with in the desert. As far as available, V-stage hoppers were collected from the desert vegetation in the vicinity for use in the experiments, but in addition, hoppers reared in cages were also made use of. In most cases, hoppers of the 1st instar or the 5th instar were employed, and were introduced into small collection cages—18 in. by 18 in.—with wire-gauze sides and a plank bottom. Fresh specimens of the various food-plants to be tested were obtained and spread on the floor of the cage. The plants were shuffled at intervals so as to eliminate chance preferences, and were carefully examined at the end of five hours to find out the extent to which each plant had been eaten.

In addition, smaller cages were used for testing each food plant separately for ascertaining whether by prolonged starvation the hoppers would take a food which they normally do not eat.

The following were the main results of the experiments conducted by him:—*Food preferences*: (1) *Bajri* (*Pennisetum typhoideum*), *til* (*Sesamum indicum*), *wekra* (*Indigofera cordifolia*), *vishani* (*Tephrosia hookeriana*) and *kanti* (*Tribulus terrestris*) were preferred to all others. (2) Experiments showed that even among the preferred plants, semi-dry or over-mature specimens were refused in favour of fresh green plants of other species, usually not much liked. Actual observations made in the desert showed, for instance, that *wekra* (*Indigofera*) and *kanti* (*Tribulus*) were always preferred to *booh* (*Aerua*) when they were in a green flourishing condition as, for instance, in July-August, but in October-November, when they had become semi-dry, hoppers were mostly found on *booh* (*Aerua*).

Plants absolutely refused: '*Ak*' (*Calotropis procera*) and *neem* (*Azadirachta indica*) were not eaten by hoppers even after 24 hours' starvation. Ovules of *ak* flowers were, however, eaten. Adults were found nibbling at *neem* leaves after about ten hours of starvation.

Plants eaten without hesitation. Among cultivated plants, the most preferred species were: *Kaling* or watermelon (*Citrullus vulgaris*), *bajri* (*Pennisetum*), *til* (*Sesamum*), *moth* (*Phaseolus aconitifolius*) and *guar* (*Cyamopsis psoraliodes*); among wild vegetation: *wekra* or *bekkar* (*Indigofera*), *bishani* (*Tephrosia*), *kanti* (*Tribulus*), *bharut* (*Cenchrus*

biflorus—catharticus), *bagra* (*Gynandropsis pentaphylla*), *santa* (*Trianthema pentandra*), *gamol* (*Panicum antidotale*), and *siwan* (*Elionurus hirsutus*). *Thuhar* (*Euphorbia neriifolia*) leaves were also readily devoured (1938).

Next in the order of preference were the following: *Booh* (*Aerua javanica-tomentosa*), *gandhil* (*Dactyloctenium scindicum-Eleusine aristata*), *bhangri* (*Blepharis scindica*), *kuri* (*Brachiaria* sp.) etc.

Plants only occasionally or rarely eaten.—They are: *bordi* (*Zizyphus rotundifolia*), *bavuri* (*Acacia jacquemontii*), *murant* (*Panicum turgidum*), *jhal* (*Salvadora persica*), *arni* (*Clerodendron phlomoides*), *phog* (*Calligonum polygonoides*), *chibbar* (*Cucumis trigona*), *dudheli* (*Euphorbia granulata*), *khip* (*Leptadenia spartium*), *Castor* (*Ricinus communis*), and *tursan* (*Citrullus colocynthis*). Of the above, *khib* and castor leaves were taken after about one hour, *phog* after three hours, *dudheli* and *chibbar* after four hours and *tursan* only after 20 hours of starvation.

It had been proposed to continue these experiments at Chachro in 1938 on the plan followed by Roonwal at Pasni, but as a result of the failure of summer rainfall and the lack of breeding in the desert areas, no further work could be done.

3. *Experiments at Ambagh,* 1938. At Ambagh, however, Mr. R. N. Batra, carried out food preference experiments with some of the common plants found on the Ambagh reks on the same plan as by Roonwal at Pasni, but confined himself only to four plants:—*Bosiri* (*Indigofera cordifolia*), *maikh* (*Tribulus*), marrand (*Heliotropium*), and *Kharzan* (*Sericostoma pauciflorum*). These trials were made in September-October and November and the experiments were extensively repeated, there being on the whole 121 replications. As a rule, about 44 hoppers were used in each experiment, and in each case the number found on each plant was noted. The results obtained are tabulated below:

TABLE IX

S. No. of Experiment	No. of duplications	Number of hoppers on each food—plant			
		Bosiri	Maikh	Marrand	Kharzan
VII—a . .	20	119	85	74	84
VII—b . .	16	63	79	42	49
VII—c . .	32	78	80	31	41
VII—d . .	17	52	80	23	47
VII—e . .	36	170	232	142	161
Total . .	121	482	556	312	382
Preference Value percentage with marrand as standard :		154	178	100	122

It is thus seen that kharzan—which was found in the Pasni experiments (1937) to have only a P.V. of 40—has a higher value than marrand at Ambagh. The other two plants—*Indigofera cordifolia* (*Bosiri*) and *Tribu-*

lus terrestris (*maikh*)—show even higher values, and as they are common food-plants in the Sind-Rajputana desert, it might be advisable to carry out similar experiments with the plants of that area also, so as to arrive at a common scale of values for all the food-plants of the locust in the Indian region.

4. *Experiments at Pasni*, 1938. In an attempt to find out the ultimate factors underlying the subtle preferences exhibited by the locust in regard to its food plants, Mr. Taqi Ahsan carried out certain experiments at Pasni in 1938. He was rather struck by the fact that a good many of the preferred food plants, such as marrand, lucerne and maize, were bright green in colour as contrasted with the lighter colour of mazoung and reghit, and also the circumstance that many of the plants disliked, as for instance, neem reghit and jhawad, were either acrid or saltish in taste.

Three series of experiments were devised, two to observe the reactions of the hoppers to differences in colour, and a third to distinctions in taste.

In regard to colour, twenty specimens of fifth instar hoppers were introduced into cages with glass-pane sides, 10·5 inches in size, kept in the open, on the floor of which the food-plant was provided on two glass dishes, one of which was covered with green cloth and the other with dull grey cloth. In one series of experiments, marrand was served in both dishes, and in the other, marrand was given on the dull grey cloth and jowar on the green cloth. The hoppers were starved for at least two hours before introduction of food and observations were taken twice, once in the forenoon and again in the afternoon. The number of hoppers attracted to the dishes was noted after five minutes.

The third series of experiments were made in a glass cage of 24-inch sides, on the floor of which twigs of salted marrand (i.e. *marrand* dipped in 5 per cent salt solution for a minute and dried) and untreated *marrand* were placed side by side, and 10 specimens of hoppers of 3rd, 4th and 5th instars were introduced.

The results of these experiments are shown below:

TABLE X

Experiment I. Marrand on green cloth versus dull grey cloth

Period	Number of Sets	Total number of hoppers	
		Green	Dull Grey
August—September	17	287	166
Percentage		63·4	36·6

Experiment II. Jawar on green cloth versus marrand on dull grey cloth

Period	Number of sets	Green	Dull grey
September . . .	6	143	63
Percentage .		69.4	30.6

Experiment III. Salted versus normal marrand

Period	Number of sets	Salted	Normal
September—October . .	13	29	73
Percentage.		28.4	71.6

These results indicate that more hoppers have been attracted to the green cloth dishes despite the quality of the plants served; and that salted marrand is discarded just as if it were reghit or mazoung.

These experiments should, however, be regarded only as preliminary ones and should be further elaborated and repeated, using a larger number of hoppers in the trials, before legitimate conclusions can be reached.

The results of the various experiments described above clearly indicate that the desert locust shows a rather marked degree of selectivity in its feeding habits. Although it is by no means monophagous, and although in the absence of a favourite food-plant it is sufficiently catholic in its tastes to get on with plants not ordinarily eaten, there is no doubt that it has a distinct aversion for certain particular plants, which in spite of their high water-content are evidently distasteful to it. The earlier experiments, as for instance Karandikar's, were, no doubt designed to test the suitability of individual plants as food for the locust, but most of the later experiments had for their purpose the testing of the selectivity of hoppers, which was found to be high enough to enable a scale of preference values being evolved.

It is rather unfortunate that most of the outbreak centres discovered in the Mekran area have happened to be rather out-of-the-way places, and it was not possible to investigate them, as their occurrence was reported at far too late a stage in their development. It is, therefore difficult to decide how far the factor of food-preference had been responsible for bringing them into existence. There is sufficient reason however, to believe that the migrating adults had been attracted by the millet crops, and that the presence of various food-plants of the locust in the immediate vicinity of the crops had served to bring about a concentration of the hoppers. On the whole, there seem to be sufficient grounds to consider that food preference does play a considerable part, possibly in conjunction with other factors, in the causation of incipient swarms.

VII. *The development of eye-stripes in hoppers*

While examining in January, 1936, a large collection of locusts representing the July incursion of 1935, Dr. M. L. Roonwal accidentally discovered the existence of two different types of striped compound eyes among them [Roonwal, 1936]. Out of 727 specimens examined, 578 locusts (about 79·3 per cent) had six vertical stripes in their eyes, while 149 (about 21·7 per cent) had seven eye-stripes. In his note in *Current Science,* he writes: 'Since the number of stripes in the large number of specimens examined was invariably either six or seven, the two types cannot be regarded as a case of simple variation. The origin of this difference is, however, obscure. Whether the difference is inherited in a genetic way can be shown only by extensive breeding experiments.'

With the object of tracing the development of eye-stripes in the hopper stages, he followed the progress of rearings of more than 120 isolated hoppers in cages early in 1936 and found that stripes were noticeable in all the hopper stages including the first instar. He also noticed that the anterior margin of the eye functioned as the active growth region, in which a new stripe made its appearance during the interval between two successive moults. According to him, one additional stripe appeared after each moult, in both the six-striped and the seven-striped types, except in the case of the third stage in which two stripes were added in the seven-striped form, but only one in the six-striped one. Since the difference between the two types appeared to be a deep-seated one, he came to the conclusion that the distinction might be a genetic one. As, on an examination of a large number of specimens of the *gregaria* phase collected from swarms, it was noticed that they invariably had six eye-stripes, wherever stripes were distinguishable, and as most of the seven-striped locusts were of the *solitaria* phase, it looked as if the stripe characters might indicate a differentiation of phase.

To see if the stripe characters are heritable, Roonwal tried crossing six-striped forms with seven-striped ones, and subsequently 8-striped types with 6-striped, and also inter-breeding of 5-striped males and females, and carried the rearings to the F_2 generation. The only clear indication that he could get as a result was that the 6-stripe character was dominant over the 7-stripe one, but it was found that in the case of the crosses between 8-striped and 6-striped types and the pairing of 5-striped males and females, the resulting progeny was made up of 6 and 7-striped forms and did not include any 8-striped or 5-striped individuals.

In view of the possibility that a study of the chromosome characters of these types might reveal the existence, if any, of genetic differences, several living specimens of adult males and corresponding hopper stages of 5-striped, 6-striped and 7-striped forms were sent in 1937 by air-mail from Karachi to Professor J. J. Asana, Head of the Department of Biology, Gujarat College, Ahmedabad, for favour of examination for chromosome characters. He very kindly made a careful study of the material sent, and after examining the sections thoroughly reported as follows : 'Regarding the cytological observations on the material supplied to me, the most that I can say is as follows: No differences have been observed in the number of chromosomes revealed by the male germ-cells of the various types supplied. A detailed study of the chromosomal behaviour of these various types during synapsis has not, however, been made.'

With a view to examine the possibility of the eye-stripe character being the result of environmental conditions, experiments were devised at Karachi to test the effect of exposing hoppers to sun-shine during rearing

as against rearing them in shade, as also certain others to test the effect of crowded *versus* isolated rearing. At Ambagh, various experiments to test the effect of different foods on the eye-stripe character were also carried out. Incidentally, the development of the eye-stripes was carefully followed from moult to moult in well over 300 cases at Ambagh and Karachi by Mr. R. N. Batra and Dr. S. Mukerji respectively during the years 1936, 1937 and 1938. Both of them found that there was a definite correlation between the number of moults passed through in the hopper stage and the number of eye-stripes found in the adult condition [Mukerji and Batra, 1938].

A reference to Statements H-1 and H-2 giving some of the results of the rearings carried out by Mukerji and Batra respectively at Karachi and Ambagh, would show that there is a regular and definite addition of an eye-stripe with every moult. The first hopper instar has only a single brownish stripe dividing the eye-space into two halves—the anterior and posterior space (as inter-stripe). A short time before the first moult is due to take place, the second stripe makes its appearance at the anterior margin of the eye, so that just prior to the moult, there are two stripes present. After the moult is over, the second stripe is found to have shifted slightly backwards leaving a blank space extending to the anterior margin of the eye. By the end of the second stage, again, a new stripe appears at the margin of the eye, which similarly moves backward during the second moult, so that at the beginning of the third instar there are three stripes. By the end of the third instar, a fourth stripe is added. Similarly an additional stripe appears at each moult, so that at the end of a normal five-instar life-history, six stripes are found in the adult.

In many hoppers, it was found that an extra moult occurred at a stage prior to the turning up of the wing-pads—characteristic of the normal fourth instar. This moult may for practical purposes be considered to be interpolated between the regular III and IV moults. In all such cases, an extra stripe was observable in the adult, there being seven stripes in the eyes.

In some instances, both Mukerji and Batra met with cases of two extra moults, one of which was presumed to be an extra II moult, and the other was either an extra III or an extra IV one, and in such cases adults with 8 eye-stripes were produced.

In one case, Mukerji met with, during his rearing experiments, a hopper, which went through only four moults and transformed into an adult with crumpled wings and only five eye-stripes. Mukerji subsequently found quite a large number of adults with 5 eye-stripes in a crowded rearing cage at Karachi in September-October 1936. Some of them had crumpled wings, but others had their wings and limbs fully developed though they were mostly under-sized. It is presumed that all these had passed through only four moults. Key and Edney [1936] while breeding a stock culture of *Locusta migratoria migratorioides* at London, met with three cases of precocious adults which had crumpled wings and were evidently forms that had moulted into adult stage directly from the fourth instar. According to Predtchensky [1935. No. 11], Telenga working at Khorezm (Khiva) found that some of the larvae (*Schistocerca*) fed on lucerne moulted into the imago directly from the 4th instar, and that these adults had shortened wings and elytra and were under-developed.

Apparently these should be considered to be of the same category as Key and Edney's 'precocious' adults.

A similar correspondence between the number of eye-stripes in the adult and the number of instars passed through in the larval stages has been noted in the Bombay Locust—*Patanga succincta*, the Red Locust—*Nomadacris septemfasciata*, and *Colemania sphenarioides* (Deccan Grass-hopper)—[Rao and Gupta, 1939]. Volkonsky [1938] working at Institut Pasteur at Algiers has observed a similar correlation in *Anacridium aegyptium* and *Anacridium moestum* and made the following remarks in a letter to the writer in August 1938: 'It seems the relation between stripes and instars discovered in the Desert Locust is a general rule for all species possessing eye-stripes. It is consequently of great value for the study of instars under natural conditions.' In a few caes, where certain larval forms of grass-hoppers, such as *Caloptenopsis*, *Catantops* and *Acrida*, were reared in 1937, an eye-stripe was found to be added at each moult.

It may for all practical purposes, therefore, be taken for granted that a direct correlation between the number of stripes and the hopper instars has been established. In the case of the desert locust, all the forms collected from swarms have been found to possess six eye-stripes, while seven-striped and eight-striped individuals have been noticed to be mostly of the *solitaria* phase, so that the stripe character should be taken to be of significance from the point of view of phase. A five-instar life-history is the rule in *gregaria* breeding in both males and females and would postulate more rapid developmental processes than in *solitaria* breeding, wherein often six, and sometimes even seven, instars may be passed through by males and females.

VIII. *Effect of crowded breeding on the number of eye-stripes*

From the statement given in *Tables H-1* and *H-2*, it may be seen that very little difference was perceptible, so far as the stripe character was concerned, between those reared exposed to sun-shine and those reared in shade, except for the circumstance that those kept in the sun were quicker in development and healthier and that the great majority of those kept in shade died during rearing. Again, differences in the food provided did not indicate any marked influence on the character of the eyestripe type produced.

Since swarms of the *gregaria* phase were solely made up of the type of adults possessing six eye-stripes, and the type with seven-triped eyes was met with only among the *solitaria* adults, it was considered likely that crowded breeding may be intimately connected with the dominance of the six-striped character.

In order to test the validity of this hypothesis, various attempts were made at Karachi during the years 1936, 1937 and 1938 to rear hoppers under varying degrees of crowding. In certain cases, small wire-gauze cylinders 2 in. to 3 in. in diameter were used to confine about half a dozen hoppers in each, as against hoppers reared singly under similar conditions. It was found that most of the partially crowded hoppers died sooner or later, but wherever hoppers reached the adult stage they were of the six-striped type, whereas those reared isolated were mostly of the 7-striped type (*vide* Statement H-1, *Partially crowded* versus *Isolated*). In other cases, Mukerji used oviposition cages—1 ft. by 1 ft. by 1½ ft. high—or rearing cages 1½ ft. by 1 ft. by 1½ ft. with wire-gauze sides and plank bottoms, for tonfining good numbers of hoppers, varying from 100 to 1,200, for trials of crowded rearing. Even in these cages much mortality of hoppers was experienced and in some instances, barely 5 to 10 per cent. of the original number survived to reach the adult stage.

TABLE XI

The results of crowding on the number of eye-stripes

Time of starting experiment	Original number of hoppers introduced	Date of adult emergence and total number of adults	5-striped	6-striped	7-striped	8-striped
			M — F	M — F	M — F	M — F
1936						
August . .	800	26 Sept.	60	Several	Several	*Nil.*
September . .	300	22 Oct.	17	Several	Several	*Nil.*
1937						
9th February .	120	March	*Nil.*	21 — 8	1 — 7	*Nil.*
		April	*Nil.*	7 — 1	8 — 23	*Nil.*
		May	*Nil.*	0 — 1	0 — 1	*Nil.*
TOTAL .		78	*Nil.*	28 — 10	9 — 31	*Nil.*
2nd April . .	150	May				
TOTAL .		28.	*Nil.*	14 — 3	5 — 6	*Nil.*
1st May . .	530	June				
TOTAL .		48	*Nil.*	23 — 11	9 — 5	*Nil.*
24th May . .	320	June	*Nil.*	0 — 1	3 — 7	*Nil.*
		July	*Nil.*	6 — 3	1 — 1	0 — 1
TOTAL .		23	*Nil.*	6 — 4	4 — 8	0 — 1
31st May . .	110	July				
TOTAL .		11	*Nil.*	6 — 3	1 — 1	*Nil.*
7th July . .	275	August				
TOTAL .		22	1 — 0	11 — 9	1 — 0	*Nil.*
13th July . .	500	August				
TOTAL .		25	5 — 2	*Nil.*	9 — 9	*Nil.*
29th July . .	1200	September				
TOTAL .		30	3 — 5	10 — 11	0 — 1	*Nil.*
1938						
January– February – March . .	148 Introduced in batches	Mostly end of April	2 — 0	0 — 2	*Nil.*	*Nil.*
		May	3 — 1	0 — 1	*Nil.*	*Nil.*
TOTAL .		9	— 1	0 — 3	*Nil.*	*Nil.*

From the above table, it may be seen that in September 1936, about 60 adult locusts were found including full-winged and brachypterous forms, males as well as females, with only 5 stripes in their eyes, appearing along with other adults with 6 and 7 eye-stripes, in a mass rearing cage of 1½ ft. size containing about 800 hoppers. In a second instance in a cage where 300 hoppers had been crowded-in in September, about a dozen adults with 5 eye-stripes were found as also about half a dozen hoppers which developed into 5-striped adults subsequently, in addition to 6 and 7-striped forms.

These experiments were continued in 1937 from February onwards till September. During the months February to April when the temperatures were comparatively low, equal numbers of 6 and 7-stripes were produced. With a considerable rise in temperature in May and June and with higher concentrations of hoppers, a tendency towards a higher proportion of 6-striped forms was noticeable.

Five-striped forms did not develop till August-September, when a fair number of them were again noted along with 6-striped forms. Five-striped forms were next met with in May, 1938, and presumably their appearance at various times during the years 1936, 1937 and 1938 is to be correlated with the prevalence of high temperatures, (which are commonly met with at Karachi in May, and September-October), in association with crowded breeding.

Volkonsky [1937] found in the course of rearing hoppers of *Anacridium aegyptium* that under crowded conditions the males went through only five instars—one instar less than the females, while, when bred isolated both males and females passed through six moults. As the number of stripes in the eye is dependent on the number of moults Volkonsky's experience serves to confirm our results.

In seeking the *rationale* of the phenomenon of a reduction of instars under conditions of crowding, the number of instars passed through by different species of Acrididae might be examined. In *Locusta migratoria* the usual number is five, but Nikolsky [1925] has recorded an instance f six stages in a female of ph. *solitaria*. In *Locusta migratoria capito* Sauss, Zolotarevsky [1933] found that the females went through six instars, while among the males, the solitary ones had five stages and the *gregaria* ones, six. In *Locusta m. migratorioides* the usual number is five, but Key [1936] found, in rearings from two particular egg-batches, that all the females had six instars, though the males had only five. In the Moroccan Locust (*Dociostaurus maroccanus*), the Italian Locust (*Calliptamus italicus*), and the Brown Locust (*Locustana pardalina*), all of which form hopper bands, there are only five larval stages [Melis, 1934] [Uvarov, 1928]. The *gregaria* phase of the Desert Locust (*Schistocerca gregaria*) has only five instars, but Ballard and his co-workers [1932] state: 'The number of nymphal instars is generally five and rarely six. The majority of nymphs which pass their life through six stages emerge into female adults, few emerging into males'. The six-instar type reported had been, it is presumed, met with among hoppers reared under conditions of isolation. In our rearings, carried out under varied conditions, we have met with cases of four, five, six and seven nymphal instars in the desert locust. In *Oxya velox*, the males invariably pass through six moults, while 50 per cent. of the females have an additional moult [Rao, 1921]. In *Hieroglyphus banian*, most of the males have six nymphal instars, though a few may pass through an additional moult, but all the females have seven instars, [Coleman and Kunhikannan, 1911]. In *Colemania sphenarioides* Bol., 5 or 6 stages irrespective of sex have been recorded by Coleman [1911]. In the Red Locust, *Nomadacris septemfasciata*, Serv.

there are six stages in the development of the hopper, and the adult appears at the end of the sixth moult [Faure, 1935]. In *Patanga succincta* L. (Bombay Locust), seven moults would appear to be common and an eighth moult may also occur [Lefroy, 1906].

Examining the data compiled above, it may be seen that the number of hopper stages is higher in species of grass-hoppers, such as *Oxya velox* *Hieroglyphus banian* and *Colemania sphenarioides*, in which the hoppers do not form swarm bands. The highest number is seen in *Patanga succincta*, where the hoppers never join into bands, while in *Nomadacris* where bands are formed, the number of instars is less by one, although both are locusts of equally large size. In all species of locusts where *gregaria* bands are the rule, five instars would appear to be normal, while in *Locusta m. capito*, in which gregarization does not seem to reach such a high pitch as in other sub-species of *Locusta*, the number of moults is higher. On the other hand, wherever hoppers are reared under conditions of isolation a tendency is noticeable towards the development of an extra hopper instar. In other words, the more intense the crowding in the hopper stages and the more active the gregarious life of the hopper bands, the fewer the hopper instars.

Rate of growth of hoppers

In this connection, the rate of growth during the hopper stages may be examined. Bodenheimer and others [1930] have worked out figures for *Schistocerca* and Key [1936] and Duarte [1938] for the African Migratory Locust. Karandikar had also worked out the rate of increase in the weight of hoppers from stage to stage in *Schistocerca* in 1932 at the Pasni Field Station.

TABLE XII

Rate of growth in Schistocerca gregaria

Stadium	Bodenheimer, 1930		Karandikar (Pasni), 1932	
	Average weight in grms.	Rate of increase	Average weight in grms.	Rate of increase
I instar	0·0232		0·018	
I-II		2·07		2·06
II instar	0·0481		·037	
II—III		1·93		2·68
III instar	0·0953		0·099	
III—IV		2·12		2·81
IV instar	0·2311		0·278	
IV—V		2·28		1·89
V instar	0·5280		0·525	
V—A		2·81		
Adult Fresh fledged	1·4860 (female)		1·310 (male)	
Proportion of weight of I instar to weight of adult	1 : 64·6		1 : 72·9	

TABLE XIII

Rates of growth in Locusta migratoria migratorioides

Stadium	Key—1936		Duarte—1938			
	Average weight in grms.	Rate of increase	Average weight in grms.	Rate of increase	Average weight in grms.	Rate of increase
	(Hoppers kept in high humidity)		(*Gregaria* Males)		(*Gregaria* Females)	
I instar . . .	0·21		0·0143		0·0143	
I—II . . .		2·24		2·32		2·63
II instar . . .	0·047		0·0332		0·0376	
II—III . .		2·47		2·16		2·06
III instar . .	0·116		0·0718		0·0774	
III—IV . .		2·47		2·42		2·68
IV instar . .	0·287		0·1737		0·2075	
IV—V . .		2·92		2·35		2·35
V instar . .	0·837		0·4085		0·4870	
V—A . . .		1·94		2·21		2·56
Adult . . .	1·625		0·9040		1·2507	
Proportion of weight of I instar to that of adult . .	1 : 77·4		1 : 63·2		1 : 87·5	

It is seen from the data tabulated that a hopper of the 1st instar increases its weight approximately 63 to 87 times before it assumes the adult stage. It may also be noted that at each stage, the rate of increase is generally more than double the previous instar.

Theoretically, growth occurs as a result of cell-division, and if the cell-divisions of all parts of the body occur simultaneously, the insect would be doubling its weight and size before moulting into the next stage. In case such a doubling of mass were to occur regularly at each moult, the newly hatched hopper will have to pass through seven instars before it can reach a mass of 64 times its weight, and, probably, eight moults to attain an increase 87 to 100 times.

While in the case of *solitaria* hoppers, which generally develop in comparative security hidden among bushes, the process of moulting is not apparently a serious problem, the situation is very different among bands of actively moving *gregaria* hoppers. As is well-known, a hopper undergoing a moult is in a helpless and defenceless condition, and is liable to attack not only by predators but also by other hoppers, unless the latter

are also moulting. As, very often, moulting occurs in fairly exposed situations, the danger of becoming a casualty is great, and natural selection will obviously act in favour of the survival of forms which can complete their larval development with the least number of moults. It may be presumed that in cases where the number of moults is thus cut short, the casting off of the cuticle will occur at longer intervals, though the growth of the tissues by cell-division may continue without interruption, the result being that the rate of increment between successive moults is raised from 2 times to 2·25—3 times. It also appears fairly certain that the main factor in the curtailment of the number of moults is the high degree of metabolic activity of the hopper, and that conditions favourable to a reversion to a larger number of moults would be brought about by lowered metabolic activity.

During the growth period of the solitary phase hopper, the rate of growth is obviously not rapid and cell-divisions in the hypodermis keep pace with those of the rapid of the body, so that the time of moulting more or less coincides with that of the theoretical doubling of the body-weight. On the other hand, in the gregarious phase, the growth of the internal tissues is more rapid than that of the hypodermis, with which moulting is organically connected, the result being that the body-weight is often nearly treble between two successive moults, instead of the normal doubling in the case of the solitaria hopper.

The state of development of a hopper is ordinarily judged by external characters, such as the size and shape of wing-rudiments, and the number of antennal segments and eye-stripes,—all of which are structures connected with the hypodermis, and consequently, there is at times the likelihood of a wrong reading of the state of development of the internal tissues being obtained therefrom. An interesting illustration of this circumstance was met with in the course of rearing experiments. In one of the cages, a large number of locust adults were bred out, among which there were several individuals with 5 eye-stripes, some possessing crumpled wings and the others well-developed ones. All individuals with 5 stripes were picked out and kept segregated in a cage, and in due course, normal pairing occurred as well as oviposition, from which hoppers duly emerged. Although adults with five eye-stripes should be considered to represent individuals precociously developed from IV instar hoppers, it is seen from their ability to breed normally that their internal tissues were normally developed.

In summing up the above observations, the writer would venture to remark that the view generally held of regarding five instars as the normal number for locusts in particular and for Acridids in general, should be considerably modified. In solitary grass-hoppers, the normal number of larval instars would appear to be almost always more than five—generally six and sometimes seven or more, and the curtailment in the number of moults would appear to be one of the lines taken in the evolution of solitary species into gregarious ones.

IX. *Coloration of locust in relation to a change of environment*

Field observations have shown that the hoppers of the desert locust very often present a striking resemblance in colour to the vegetation on which they happen to be found. Hoppers found on '*booh*' (*Aerua*) and '*kanti*' (*Tribulus*) are always a bright ashy blue, while those seen on '*wekra*' (*Indigofera*) and '*marrand*' (*Heliotropium*) vary from a bright to a dark green in colour. At the end of the breeding period when vegetation is drying up hoppers usually assume a brownish yellow or hay

colour. In certain cases, one may find along with typical green hoppers, some with brownish patches on the sides of the thorax, apparently indications of the appearance of *gregaria* characters following a local rise in the density of hopper concentrations.

Adult locusts have also been found, to a certain extent, to assimilate the general coloration of their surroundings. Specimens of locusts collected from the 'black gravel' (Siah-pat) areas in the hilly parts of Baluchistan and Sind, have always been found to be very dark in colour, the stripes on the sides, the elytra, the eyes, and the antennae being all dark bluish brown. Adults found in the sandy areas of Rajputana in autumn are of a light yellow or hay colour, in consonance with the general colour of dry vegetation (*Vide* Pl. 23, Figs. 3 and 4). On the other hand, during the period of monsoon breeding in the Sind-Rajputana desert when luxuriant vegetation is seen everywhere, numerous instances of locusts with a distinct greenish tinge have been noticed. These are generally of two categories. One of them is made up of the new generation produced in August-September, in which there is a light green suffusion all over the body, especially on the prothorax, the elytra, most of the veins of the wings, the legs, and the face and mouth-parts. Apparently, the green tinge is due to the green blood shining through the veins and the chitin. The green type of locusts persists while the vegetation is green, and many quickly develop deep yellow wings and in certain cases, green coloured females were found to have already laid eggs at the time of capture in September. This type usually disappears as the vegetation begins to dry up. The other category is comprised of locusts of the old generation migrating in June-July into the desert from western rek areas. These too were found to possess patches of green colour on the prothorax, the elytra and the face, developed—presumably—in response to the growth of luxuriant green vegetation—especially grasses—all over the desert. Similar green forms were noticed also in the Lasbela area in 1936 and 1937 during the monsoon season.

The general coloration of the solitary type, moreover, should be deemed to be of the type of protective coloration. While the pink colour of young *gregaria* swarms, and the bright yellow of mature locusts make them very conspicuous in the field, the scheme of coloration found on the *solitary* type—consisting in the main of a median light stripe on the back with a set of light and brown stripes along the sides—is designed to serve as a camouflage helping the insect to merge itself thoroughly with its environment (*Vide* Pl. 22). For, an insect of fairly large size like the desert locust would, when resting on a bare patch of ground, be a fairly conspicuous object if wholly pink or yellow, but the colour pattern characteristic of the *solitaria* type, made up of the mid-dorsal and the lateral stripes, serves to break the monotone, and create the semblance of a grass-stem or a dead twig lying on the ground. As a matter of fact, even men with long field experience have often failed to detect the presence of the *solitaria* locust resting close by until it actually flew up. When after a short flight the locust settles on the ground, it merges with its surroundings so perfectly that it looks almost as if it had vanished.

It is only on rare occasions that the solitary locust exhibits any active movements, as when courtship is in progress, or the insect is trying to get under a bush to escape the intense heat of the mid-day sun. Its protective coloration ensures its safety, so long as it is perfectly still. Any abrupt movement breaks the magic and renders the locust liable to detection and attack.

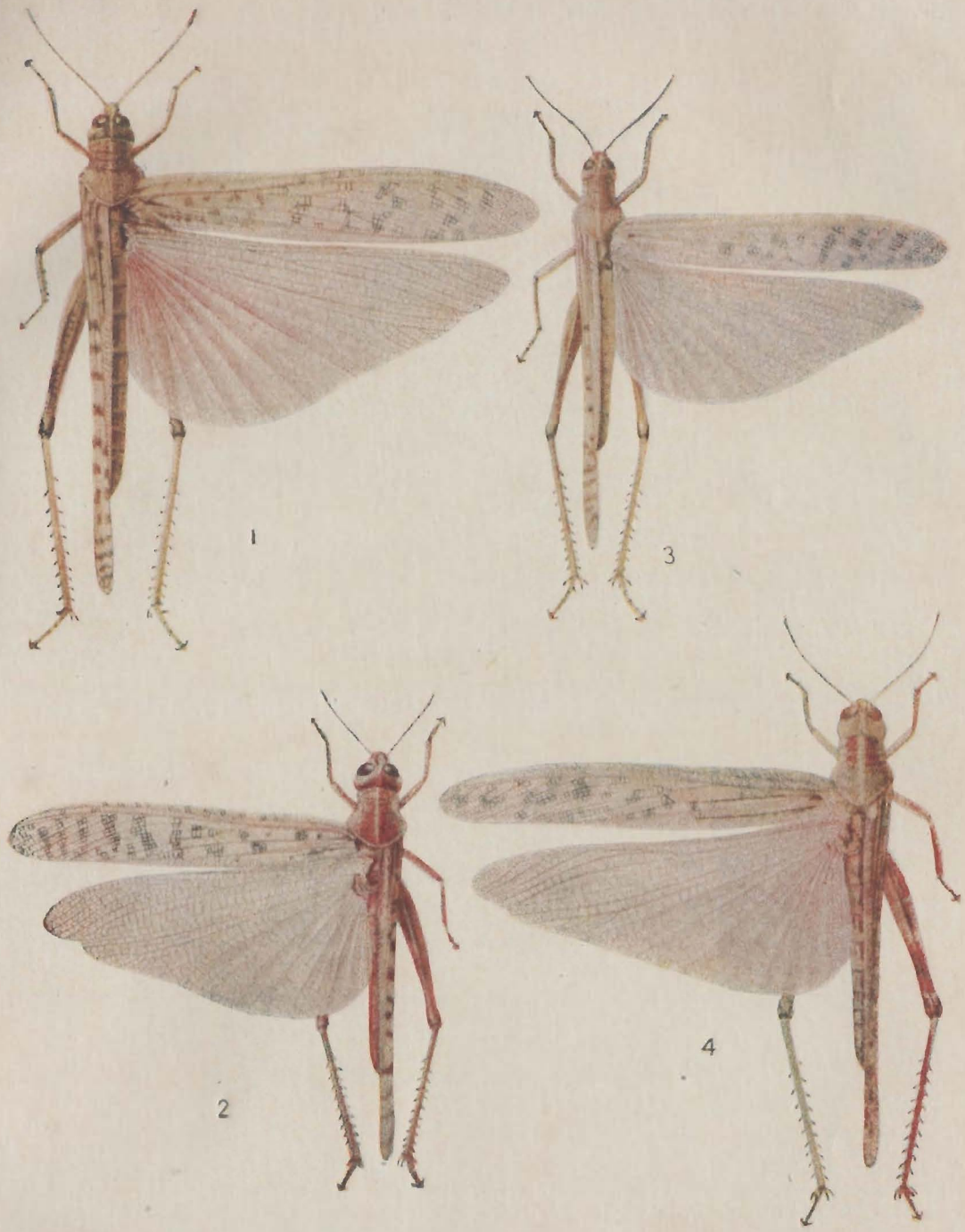


Plate 23.—Desert Locust adults:

Fig. 1. *Gregaria* phase: wings pinkish; Fig. 2. *Solitaria* adult: wings hyaline, body-colour pink; Fig. 3. Young *solitaria*: body dry grass colour; Fig. 4. Young *solitaria*: body-colour greenish, green patches on elytra, pronotum, etc. adapted to green grass environment.

During the years when incursions of pink locusts occurred at Pasni as for instance in June 1932 and July-August 1935, it was noticed after a few days that pink-coloured locusts were gradually disappearing and were being replaced by forms possessing distinct stripes of the type associated with the solitary phase. There was little doubt that the real fact was that the immigrant locusts were gradually acquiring the *solitaria* pattern of coloration. In order to test this phenomenon under experimental conditions, a small field cage 3 ft. by 3 ft. square and 3 ft. high was set up in a field at Quetta, over a natural environment made up of stone and gravel with a few plants growing in between in June-July 1932, and about a dozen specimens of typical pink locusts with pink body and legs, unstriped eyes and elytra with prominent brown patches, were introduced into the cage. Feeding was done regularly every day, and periodical observations made indicated that the locusts spent much of their time basking in the sun. In the course of a week, it was noticed that a greyish colour had been assumed and that faint stripes had appeared on the body, as well as in the eyes. In about two weeks the stripes were distinct and the transformation of the pink locust into the typical *solitaria* coloration was complete.

In locust adults recently transformed from hoppers, the colour pattern commonly seen on the prothorax of the fifth stage of the hoppers—consisting of a series of light dots on a darker back ground but without any

TABLE XIV

The effect of Sunlight on Gregarious Adult Eyes

Date of experiment	Remarks on condition of eyes		
	SR1 (Sunshine) 2 females 4 males	SR2 (Sunshine) 5 females 3 males	S1 (Shade) 2 females (control) 3 males
26 May 1936 .	Eyes claret coloured. No stripe visible, except one at anterior end of eye.	Eyes as in SR1 .	Eyes uniformly claro coloured. No stripe visible.
1 June 1936 .	In three locusts the stripes have cleared; in the other three, not visible.	In four locusts the stripes have cleared; in the other four, not visible.	Eyes as before; one male died.
28 June 1936 .	Four locusts with clear stripes; the other two without stripes. (One male and one female died).	All locusts with clear stripes. (Two males and two females died).	Eyes as before except in one female where the two antereor stripes are faintly seen.
28 July 1936 .	Stripes clear in all (One male died).	Stripes clear in all.	Do.

dorsal or lateral stripes—usually persists for a short time (Plate 21, Fig. 2). At Karachi, it was found that if such adults were kept in shade, the hopper pattern persisted for over ten days, whereas if they were kept exposed to the sun, the adult coloration was assumed fairly quickly.

Usually the eyes of fresh adults transformed from black-coloured, cage bred hoppers are without stripes, and even if any stripes are present they are very faint. Experiments carried out at Pasni in 1936 showed (Table XIV) that in the case of specimens kept in the sun, light grey opaque inter-stripes gradually made their appearance converting the eye into a striped one, while in those kept in shade there was no such development, Evidently, stripes are present in the eyes of all individuals *gregaria* or *solitaria*, and in cases where they are not visible they apparently exist in a latent condition, being masked by brown superficially.

Painted-box experiments—Dr. M. L. Roonwal, 1936

In 1932, Faure conducted a series of experiments with hoppers of *Locustana pardalina* (Walker) and of *Locusta migratoria migratorioides* R. and F. in South Africa, with the object of finding out how far they were able to assimilate the colour of their environment. As little was known in regard to the capabilities of the hoppers of the desert locust, Roonwal devised certain painted-box experiments at Pasni to study their effect on the coloration of the hoppers. Hoppers were reared in small wooden boxes (9·5 cm.×3·5 cm.×12 cm.), the wooden sides of which were painted inside in different colours. The boxes were open only at the top, which was fitted with a wire-gauze covered sliding lid. The boxes were kept in the shade of the laboratory building, and care was taken not to expose them to direct sunlight. "To start with, green hoppers (of 1st instar) were taken in nearly all cases, except in one where a black hopper was used'. The results obtained therefrom are tabulated below. Out of nearly 64 experiments started, only 19 reached a sufficiently advanced stage to permit of deductions being made, and the rest terminated with the death of the hoppers in the first or second instars.

TABLE XV

Results of printed-box experiments: Roonwal—1936

Colour of the inside of the painted box	Details regarding the conduct of the experiments; the number of insects that reached the adult stage etc.	Resulting colour of the insect under experiment	
		Old hoppers	Adults
1. *Lemon yellow* .	Nine experiments were started; 5 died in 1st instar; 2 in 2nd; one was reared up to 4th and one to adult stage.	Bright yellowish green	Light green
2. *Prussion blue* .	Nine experiments started; 6 died in 1st stage; one in 2nd. The rest were reared to adult stage.	Fawn or green base with black markings	Brownish or pinkish grey
3. *Mahogany* . .	Nine experiments started; 5 died in 1st stage; 2 in the 2nd; one was reared to the 3rd, and one to adult.	Fawn or green base with black markings	(Colour not noted).
4. *Black* . .	Seven experiments started; 4 died in 1st stage; one up to 4th stage, two reared up to adult stage.	Dark green or dirty fawn base with black markings.	Smoky brown or Ash-coloured

TABLE XV—(*Contd.*)

Colour of the inside of the painted-box	Details regarding the conduct of the experiments ; the number of insects that reached the adult stage etc.	Resulting colour of the insect under experiment	
		Old hoppers	Adults
5. *Dark green*	Eight experiments started ; five died in 1st stage ; one in 2nd ; one reached 3rd stage ; and one adult stage.	Bright green	Light green
6. *Signal red*	Out of nine experiments, 7 died in 1st stage. The rest reached adult stage.	Dirty green or orange	Grey with violet tinge, especially on hind-legs
7. *White*	Ten experiments started ; six died in 1st stage ; two were reared up to 4th ; one to 5th ; and one to adult stage.	Generally greenish white	Whitish fawn
8. *Light ochre* (Unpainted wood)	Out of three, one died in 1st stage ; one was reared up to the 4th ; and one up to adult stage.	Pale green with or without yellow tinge	Dull brown

Roonwal makes the following remarks in regard to the results obtained. 'It will be seen from the table that some colours were apparently simulated, whereas in others the results were indefinite. Colours which were simulated to a greater or less extent were: light yellow, black, dark green and white. Hoppers reared in the mahogany coloured boxes became fawn-coloured in the fourth stage. This is not regarded as due to the mahogany box, since a hopper reared in the prussian blue box also became fawn. Moreover, fawn colour sporadically appears in solitary hoppers reared in identically coloured cages, where the factor of the environmental colour cannot be correlated with the colour of the hopper. It is thus seen that the locust can to a greater or less extent simulate certain environmental colours.'

Faure [1932] obtained a majority of 'good' or 'fair' resemblances on white, black, grey, yellow and brown backgrounds in the boxes, but none in the cases of boxes painted green, pink, blue or with black and orange stripes. Hertz and Imms [1937], working on the relationship between the general coloration of the hoppers of *Locusta m. migratorioides*, R. & F. and the wave-lengths of the effective colours forming different backgrounds, came to the conclusion that, with the exception of hoppers reared on black, no complete adaptation of the colour of the background was observed in any instance. Nevertheless, the effects of the background colour are, according to them, clear, as they are manifested by the assumption of different shades of orange yellow blended with a variable amount of black pigmentation. As regards the production of green hoppers, they confirm the conclusions reached by Faure that they do not result in response to a green background, but are only produced in the presence of a moist atmosphere and an abundance of succulent food.

In regard to the ability that the adults of the desert locust apparently possess to adapt their general coloration to that of their environment, to which reference has been made earlier, the following observations made by Hertz and Imms [1937] on the results obtained by various workers in Germany on the colour changes shown by the Phasmid, *Carausius* (*Dixippus*) *morosus* may be of much significance '*Carausius* is able to produce more or less pigmentation according to the nature of the background, and is, furthermore, able to respond to sudden changes in background coloration by movements of the pigment granules in the hypodermal cells. The pigment granules become aggregated or diffused according to whether the insect is paler or darker in its general colour. The darkening of the animal depends upon differences in the intensity and quality of the light incident from above and reflected from below. When the under-parts of the eyes are covered with black paint, the same blackening effect is produced as with a black background. On the other hand, when a black paint is applied to the upper halves of the eyes, or over the whole of these organs, no such result is obtained. The incident light is most effective when composed of short waves and is less effective when long waves are used . . . The primary sensation of the background coloration is received through the eyes and, acting on the visual centre of the brain, apparently, induces the secretion of a hormone into the blood. It would, therefore, appear that it is this hormone which activates the movements of the pigment granules . . . It is also probable that hormones are produced, through visual stimulation, which control the development of the different pigments.'

X. *Effect of sunlight on the coloration of wings*

In recently fledged adult locusts, the hindwings are always hyaline. In cold weather there may be no development of colour for a pretty long time, but in summer a tinge of yellow usually makes its appearance within a week, signifying thereby the onset of sex maturation. When the yellow colour deepens, there is, of course, positive indication that the insect is mature.

In many specimens of locusts collected from nature, the occurrence of pink or mauve or light blue colour at the base of the wings was often noticed. During the earlier years of the locust survey work the significance of this coloration was not recognized. It was not till the year 1935, when definite proof of the migration of solitaries was first obtained, that the significance of the possession of mauve or pink patches on the wings in connection with migration, was first noted. Observations repeated during the summer and autumn migrations of 1936 and 1937 clearly showed that such a pink or mauve tinge in the wings was decidedly connected with active migration flight, being presumably the effect of the action of solar radiation on the wings, while exposed to the sun during flight. With the object of getting a confirmation of this conjecture, experiments were devised for testing at Pasni, Ambagh and Karachi.

Experimental work

While examining some of the locusts in a cage kept in the sun at Pasni during a visit in May 1936, the writer was struck by the presence of a definite tinge of pink on the hind-wing of one of the locusts, which had been exposed to sunlight by reason of a malformed elytron. This observation suggested the idea of removing the fore-wings of some of the locusts in order to test the effect of an exposure to the sun's rays.

A cage—3 ft. square and 3 ft. high—was set up at Pasni, in which some recently transformed locusts were introduced after having their right elytra removed, as well as certain others with both elytra excised. The cage was kept in the open, fully exposed to the sun, which was very bright and hot during May and June. In the course of a week or two, it was noticed that wings exposed to the sun had in all cases acquired a pink colour, which subsequently gradually deepened into mauve. By July, however, there was a change of weather at Pasni with the appearance of foggy mornings and cloudy days, as a result of which pink or mauve colour disappeared from the wings giving place to bright yellow indicative of maturity. In the case of specimens, in which only the right elytra had been removed, it was noticed that pink or mauve had appeared even in the left wing, although the colour was by no means so intense. These experiments were repeated in November-December, 1936, and again during 1937 at Pasni with similar fairly positive results (vide *Statement—J*-1).

Experiments on similar lines were carried out also at Ambagh and Karachi. The first set of experiments, set up at the end of June, in both places, did not produce any results, as on account of the advent of the monsoon, conditions of high atmospheric humidity and lack of sunshine prevailed and served to bring about the development of a bright yellow colour on the wings. In the second and third sets of experiments carried out in September and November respectively in 1936, the development of pink or mauve colour was definitely noted in the course of two to four weeks in many of the specimens. At Karachi, however, the cages had perforce to be kept in a place, where on account of the proximity of high buildings on two sides (east and west) the locusts under experiment did not get direct sunshine for more than three or four hours during the middle of the day, so that results were not naturally as definite as at Ambagh.

At Ambagh, (*Statement J*-2) Batra carried out certain interesting experiments in connection with the effect of sun-light on wing-coloration. In a few cases, he removed the right elytron as usual, but painted the other elytron black so as to prevent the sun's rays from infiltrating to the wings beneath, and found no trace of pink or mauve developing on them even at the end of a month, though there was colour development as usual on the exposed wing. In other cases, he painted both elytra black, as a result of which he found that the development of mauve or pink had been completely eliminated. In certain other experiments, he kept a small number of locusts (1) with the right fore wings removed, (2) with both elytra removed and (3) with both elytra intact, in boxes completely shut off from sunlight, as controls for a similar number of locusts kept as usual in sunlight. In these cases also, neither pink nor mauve was found to make its appearance in the locusts cut off from sunlight, though the yellow tinge characteristic of the on-set of sex-maturity developed in due course, whereas in those exposed to sunlight mauve and pink appeared as usual.

These experiments indicate that the appearance of light mauve or pink in wings even in those cases where the fore-wings had not been removed, should be considered to have been due to the infiltration of sunlight through the fore-wings. In fact, it has often been noticed that among the locusts kept under experiment, such as have had one of their elytra removed usually present their uncut side to the sun while basking

TABLE XVI

Analysis of results of experiments of the effect of Sunlight on wing coloration 1936-1938

Locality	Set No.	Period	Percentage of individuals showing colour development			Weather conditions
			Control; both elytra intact	Right elytron removed	Both elytra removed	
				1936		
Pasni . .	1	8-VI to 5-VII.	..	100%	88%	June.—days very bright and sunny; July—misty and cloudy.
	2	4-IX to 6-XII.	33%	about 100%	100%	Days mostly sunny and bright except in the mornings.
Ambagh . .	1	17-VI to July.	..	0%	..	Few sunny days in June.
	2	16-IX to 21-X.	..	100%	..	Days sunny and bright.
	3	24-X to 22-XI.	..	100%	..	Days sunny and bright.
Karachi .	1	15-VI to 10-VII.	..	0%	..	Days sunny till middle of June; cloudy and rainy thereafter.
	2	10-IX to 22-X.	..	33%	..	Days mostly bright (The cages had direct sunshine only between 10 A. M. and 3 P. M. as the place was surrounded by high buildings).
	3	22-X to 14-XII.	..	30%	..	Days mostly bright; temperature fairly low.
				1937		
Pasni . .	1	4-XI-36 to 14-II-37.	20%	80%	70%	
	2	14-IV to 17-VI.	0%	80%	20%	Days sunny.
	3	1-VIII to 9-IX.	0%	82%	87%	Forenoon cloudy in July.
	4	5-IX to 20-X.	11%	33%	23%	Foggy mornings in September—October.
	5	6-X to 21-XI.	11%	18%	27%	

TABLE XVI—(*contd.*)

Locality	Set No.	Period	Percentage of individuals showing colour development			
			Control; both elytra intact	Right elytra removed	Both elytra removed	Weather conditions
Karachi . .	1	3-IV to 14-IV	..	..	75%	Days sunny.
	2	4-V to 26-V.	..	42%	33%	Occasionally cloudy in the mornings.
	3	23-VIII to 24-IX.	33%	100%	..	Days mostly sunny.
	4	16-X to 20-XI	83%	75%	..	Days mostly sunny.
				1938.		
Pasni . . .	1	28-V to 26-VI	29%	44%	53%	Days sunny.

Ambagh—1937
October—November 1937

Locusts kept in sunlight :—		
(*a*) Right elytron removed : left painted black.	Pink or mauve developed on right wing—20 to 25 days.	None in left wing.
(*b*) Both elytra painted black .	No development of pink or mauve on either wing.	
(*c*)		
(1) Both elytra intact . .	Colour developed after 28 days.	
(2) Right elytra removed .	Right elytra : mauve in 22-27 days. Left elytra : mauve in 28-29 days.	
II. *Kept in box : shut off from sunlight.*	No development of colour.	

presumably they find the other side gets too hot for them in the absence of the fore-wing. Consequently, it often happens that a large amount of light penetrates to the hind-wing through the fore-wing of the uncut side, whereas the other hind-wing is but little exposed to direct sunlight. This circumstance possibly accounts for the development of the mauve tinge on the hind-wing of the side in which the elytron has been left intact.

On the whole (Table XVI), these experiments have clearly proved that the development of pink, mauve or light blue at the base of the hind-wings is the result of exposure to sun-light (*Vide* Pl. 23, Figs. 1 and 2; Pl. 24, Figs. 1 and 2). In nature, there is a great amount of

variation in the type of colour, as well as in the depth of the tinge developed. Pink is common in the gregarious forms, and in 1935 many of the incursion forms showed pink colour not only on the hand-wings but also on their bodies. On the other hand, mauve colour is very common among the autumn migrants found in the Lasbela and Mekran areas during the months October, November and December. In some cases, there is only a very light pale bluish suffusion at the base of the wing, and in others, the mauve is well developed. In certain cases, it is the veins that acquire a dark bluish colour, while there is no special development of colour at the base. All these differences are probably due to the degree to which the wings have been exposed to sunlight during flight. In the summer months, it is probable that migration takes place in the evening or early part of the night, while in the autumn months and in winter, the nights are cold and movements probably occur during midday or early afternoon. In the latter case, there are greater chances of exposure to sunlight, and at this time, moreover, locusts love to bask in the sun, wherefore the deep mauve of the wing-bases and also the darker body colour. Since pink colour is associated to a greater extent with the *gregaria* forms and mauve tinge with the *solitaria* individuals, an investigation into the physiology of these colour developments may throw much light on their relationship with phase.

Plate 24.—Desert Locust adults:
Fig. 1. *Solitaria* adult: body light bluish, dorsal stripe-light yellow, wings pinkish mauve at base; Fig. 2. Young *gregaria* adult, brown, dorsal stripe dark-brown, wings deep mauve at base.

Chapter II

ECOLOGICAL STUDIES OF THE DESERT LOCUST

ECOLOGY may be described in brief as a study of the reaction of the living organism to the impact of its environment. The main object of the present endeavour is the acquisition of an accurate knowledge of the life-habits and behaviour of the solitary phase of the desert locust in its natural habitat and of its powers of multiplication under various natural conditions. The ecological observations carried out under the scheme had special reference, therefore, to a study of the following factors in its environment (1) the varying seasonal and weather conditions, (2) the peculiarities of the soil in different parts of the habitat, (3) the condition of the natural vegetation, (4) the activity of natural checks—predators, parasites and diseases, (5) the density of locust population and the degree of contact between individuals, and (6) the existence of competition from other animals living in the same habitat.

The ability of a species to maintain its numbers in any particular area depends on the extent to which it can overcome the handicaps placed by its environment on its powers of multiplication. In the case of the desert locust, the powers of reproduction are fairly high. Husain and Ahmad [1936] recorded in one instance as many as 11 egg-masses laid by a single female. Even at a very modest computation, the locust can multiply 50 to 100 fold under favourable conditions, but as shown by Bodenheimer [1936], the resistance of the environment to an increase of the population is apparently very high, probably as high as 96 to 98 per cent.—since under ordinary conditions the population is more or less stationary. He attributes the mortality of the new generation to the action of (1) climate (2) food and (3) parasites and diseases.

Chapman [1931] defines 'Biotic potential as the inherent property of an organism to reproduce and to survive, *i.e.* to increase in numbers. It is a sort of algebraic sum of the numbers of young produced at each reproduction, the number of reproductions in a given period of time, the sex-ratio of the species and their general ability to survive under given physical conditions. It is the potential power that an organism has to reproduce and survive in its environment.' The biotic potential of the desert locust is circumscribed by the resistance offered by the environment—physical and biotic, *i.e.* by the adverse effect of climatic and other physical conditions and by the liability to attack by natural enemies.

Although under ordinary conditions, the biotic potential of the locust is low and is just sufficient to maintain the solitary phase population, it is obvious that it can rise steeply at times, as when a new locust outbreak makes its appearance, bringing about an enormous increase of locust population. At such occasions, apparently, an abnormal weakening of environmental resistance takes place in the form of the development of weather conditions specially favourable for breeding, or of a disappearance of natural enemies. It is, therefore, of great importance to study the various factors that govern the life-processes of the locust in its natural habitat so as to determine the exact conditions under which a rise of biotic potential leading to a new outbreak occurs.

A. GENERAL STUDIES OF ECOLOGICAL FACTORS IN THE LOCUST HABITAT

It was with the object of studying the biotic potential of the locust that ecological investigations were undertaken at typical centres of the locust habitat in the Indian area. Work was started at Pasni as early as January 1932 and continuous observations were since then in progress till March 1939. Similar work was begun at Ambagh in June, 1933, as a station typical of the summer rain area along the Mekran coast, and later on, a few stations were opened in typical centres of the Sind-Rajputana desert, *viz.*, Chachro and Sardarshahr in May 1934 and Nokh in May 1935, for recording ecological observations in the desert breeding grounds.

Intensive work was, however, concentrated at Pasni, where all the meteorological equipment needed for detailed ecological observations was provided, work at the other stations being on the whole limited to simple observations relating to temperature, humidity and evaporation in screen, soil temperature, rainfall, wind-direction etc. The following were some of the main items of work carried out at these stations :—

1. Observations on daily weather.
2. Observations on changes in the vegetation due to rainfall or drought, and their effect on the locust population.
3. Observations on the occurrence of locust breeding, concentration or emigration as the result of rainfall, wind or other unusual weather conditions.
4. Observations on natural enemies, etc.

Before giving an account of the results of the ecological work carried out at these stations, it is proposed to give a short description of the main characteristics of the areas of which they form the type.

I. *General features of the areas under observation*

(a) *The Pasni Rek area.* The coastal plain of the Pasni region in fairly typical of the strip of low country stretching from Jiwani to Sonmiani along the coast of 'British' Mekran. The Pasni Rek area (*vide Text Fig.* 4) is situated along the south-eastern edge of a flat clay plain, eight to ten miles broad, stretching from the foot of the Chakuli Range—the southern escarpment of the Kulanch Valley—to the shores of the Arabian Sea. At the south-eastern corner of the coastal plain is situated a hill—Jabal Zarain—418 ft. high—a conspicuous landmark to sailors which along with the adjoining hillock, Ras Jaddi, forms a spit of land jutting east-wards into the sea and forming the southern boundary of the shallow bay of Pasni. The town of Pasni is on the western shores of the bay, and about a mile to the north of the town, the Shadi Kaur which drains the hilly country to the north, falls into the sea at a point where the coast-line tends to curve east. [Pasni town has since been wiped out by a tidal wave caused by a submarine earthquake that occured in December, 1945].

The area of the Pasni Reks forms a fairly large sandy tract of country, about 40 sq. miles in extent, roughly triangular in outline. The southern edge, which forms the base of the triangle stretches for over 5 miles from the fishing village of Chur east-wards to the base of Jabal Zarain, while to the north the reks extend *via* Gurrani, Hadzai and Deghan almost up to the banks of the Shadi Kaur of Pasni. The third side forming the eastern limit of the area extends north from Jabal Zarain to Pasni town. The rek area is narrow between Chur and Gurrani being only half-mile to one mile broad, but further east it attains a breadth of three to four miles.

The reks form a great stretch of undulating sandy country, made up of a succession of dunes, 10 ft. to 50 ft. high, separated by hollows of

varying width, the whole area being covered by scrub vegetation of varying density. Most of the dunes are of the fixed type (Pl. 25), in which the sand has become consolidated by the infiltration of clay and salts, loose sand being confined only to a comparatively thin layer at the surface. Moreover, most of them are of the longitudinal type oriented in the direction of the prevailing winds, mostly south-west to north-east. There are, however, four very large dunes of the transverse type in the Pasni Rek area, one to two miles long and 80 to 150 feet high, in which the sands are loose and are being constantly shifted by the wind. One of them is along the beach near Chur, and the other three, Sanjar Dune, Shahigurband Dune and Mastani Dune, are situated along the northern edge of the Pasni Rek area to the west of Pasni town. They are on the whole bare except for a few stray bushes of *Calotropis* and *Aerua*, and observations made during recent years show that the dunes are slowly moving north-east at the rate of two to three feet per year.

The rek area is divided into a northern and a southern half by a long, narrow, low-lying valley, varying in width from a quarter to half a mile, locally known as 'Maidan' or 'Dhak'. It runs north-west from Jabal Zarain to Seh-Chah and thence direct west towards Gurrani, beyond which, it merges in the coastal plain. The floor of the 'Maidan' is a clayish flat covered with broken shells (*Gur* in Baloch)—bi-valve and uni-valve. and a sparse salsolaceous vegetation and a few clumps of stunted tamarisk at places.

In contrast to the more or less bare condition of the clay plain roundabout, the rek area is covered with fairly thick shrub vegetation and is, therefore, frequented by herds of camels, goats, and sheep belonging to Baloch families, some of whom shift their encampments from place to place within the area, usually not far from the drinking-water wells of the Maidan such as Gurrani Chah, Rahmat Chah, Seh-Chah and Chishani Chah (*vide* Map). Various parts of the Pasni Rek area go by particular local names. The greater part of the area south of the Maidan is generally known as the Adasti Rek, though particular parts have their own local names—Romo, Ekmach, Reho, Kohando, Jhik, Lak, Chur, etc. while in the northern area are included reks known by the name of Gurrani, Rahmat Chah, Sanjar, Shahigurband, Hadzai, Deghan, Sadi-rek, Kaledani, Kik-rek and Bambol.

Other reks of Mekran coast. Besides the Pasni rek, there are several similar other rek areas along the Mekran Coast. In the 'British' area, the important rek areas situated along the coast arranged in consecutive order from west to east are the following: Jiwani, Pishukan, Gwadar, Pasni, Rumra, Gazdan, Ormara (Pl. 26), Hingol, Pohr (Pl. 27), and Sonmiani-Ambagh-Naka Kharrari. All these have apparently been formed similarly of sea-sand blown inland by the south-west wind in situations specially favourable for sand drifting in, as the neck of isthmuses, as at Gwadar and Ormara, or along the flanks of land jutting into the sea across the direction of the wind, as at Pishukan, Pasni, Rumra and Sonmiani. All the reks present great similarities to the Pasni rek both in the character of the vegetation and their general appearance, though there is much variation in the degree of development of the dunes.

Reks of the interior. In the interior of Mekran also, as in the Kulanch and Kech valleys, rek formations are noticeable, but while in the case of the coastal reks the dunes are formed of sea-sand, the inland reks are made up of fine sand or silt derived from the loam or silt soils of inland valleys (*Vide* Pl. 28). The vegetation is also very different in these inland reks, and for instance, '*Mazoung*' (*Sphaerocoma aucheri*,

which is the dominant species on the coastal reks is never found in the interior. These silt reks are important as they are apparently suitable when wet for crowded egg-laying and giving rise to incipient swarming.

(b) *The Ambagh rek area.* The area of Ambagh is typical of the eastern reks situated in the Lasbela territory subject to the influence of summer rainfall, the Pasni area being representative of the region subject to winter rains.

In general appearance, the Ambagh reks are similar to the Pasni reks, though the dunes are mostly low and the undulations are comparatively gentle. Along the Sonmiani coast, the coast-line takes a southward bend at Guruchela and curves more or less directly south towards Karachi, and the Sonmiani-Naka Kharrari reks form a sandy strip of country one to two miles wide running parallel to the sea coast. Though most of the dunes are covered by scrub vegetation and are of the fixed type, a few fairly high bare dunes of the moving type may be seen at some places adjoining the beach (see Pl. 29).

The vegetation on these reks differs from that of Pasni by the comparative rarity of *marrand* and the relatively greater dominance of *kharzan* and *balibur* (*Aerua javanica*).

(c) *The Chachro, Nokh and Sardarshahr desert areas.* These three areas, which were continually under observation, for over four years, are part of the Sind-Rajputana desert. The general features and the climatic and vegetational characteristics of the desert have already been described in Section II, and much of this description is applicable to these three areas. It should, however, be borne in mind that the great Indian Desert covers an enormous extent of area, which runs south-west to north-east in a broad arc—about 100 miles wide from the Runn of Cutch through the territories of Sind, Jaisalmer, Khairpur, Bahawalpur and Bikaner to Jaipur, in fact from about the 24th Degree N. Lat. and 69th Parallel E. to the 29th Deg. N. Lat. and 76th Parallel E. There are, therefore considerable minor differences in the physical, climatic and vegetational features of these areas.

The Chachro station is typical of the southern parts of the desert, comparatively more humid and has denser vegetation. Some of the characteristic species of the southern desert are *'thohar'* (*Euphorbia nerüfolia*) and *'kumbat'* (*Acacia senegal*). The Nokh area represents the conditions prevalent in the central parts of the desert, *viz.* north Jaisalmer, Bahawalpur and west Bikaner. It is comparatively drier and the vegetation includes 'lana' (*Haloxylon salicornicum*) not found in the south and *'siwan'* grass (*Elionurus hirsutus*), which are dominant in parts of these areas. Sardarshahr is, on the other hand, representative of the eastern end of the desert, where the dunes are comparatively low and bare. Vegetation is, on the whole, scanty, but much of the country is cultivated.

II. *The general meteorological equipment at the stations and the nature of observations*

The habitat of the desert locust lies in sparsely populated desert areas in which there are very few meteorological recording stations, so that very little exact information in regard to the meteorology of such locations was at first available. Although Pasni is a second-class observatory of the Indian Meteorological Department, from which daily observations are being transmitted to Poona by the Sub-Postmaster, these records were not of the kind required for ecological work, for which only such observations as were made in the actual situations where locusts live and

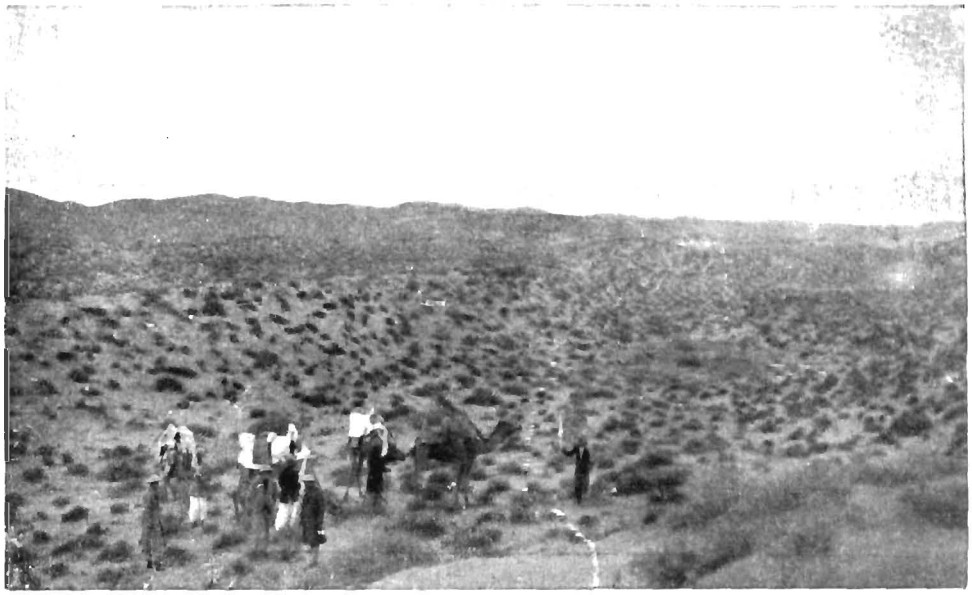


Plate 25.—*A part of Sanzar rek in the Pasni rek area* : Showing the undulating country with high dunes and hollows ; all covered with low scrub vegetation. In the distance are seen the high bare dunes (50 to 120 ft. high) of shifting sand

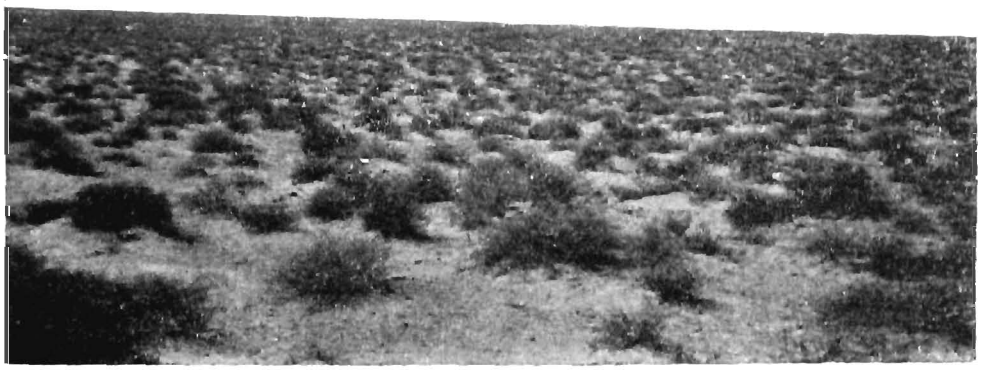


Plate 26.—*Rek area at Ormara*— February 1932: Vegetation rather dried up for want of rain; composed mostly of Mazourg—(*Sphaerocoma aucheri*) and to a less extent Marrard (*Heliotropium undulatum*) and Barshonk (*Panicum turgidum*). Few locusts were seen owing to the dry conditions.

Plate 27.—*Coastal reks in the Pohr-Hingol area in Lasbela* : April, 1932. The reks cover a large area along the coast. The river to the left is the Pohr, and the hills in the distance the Hara Range. Vegetation rather dry for want of rain.

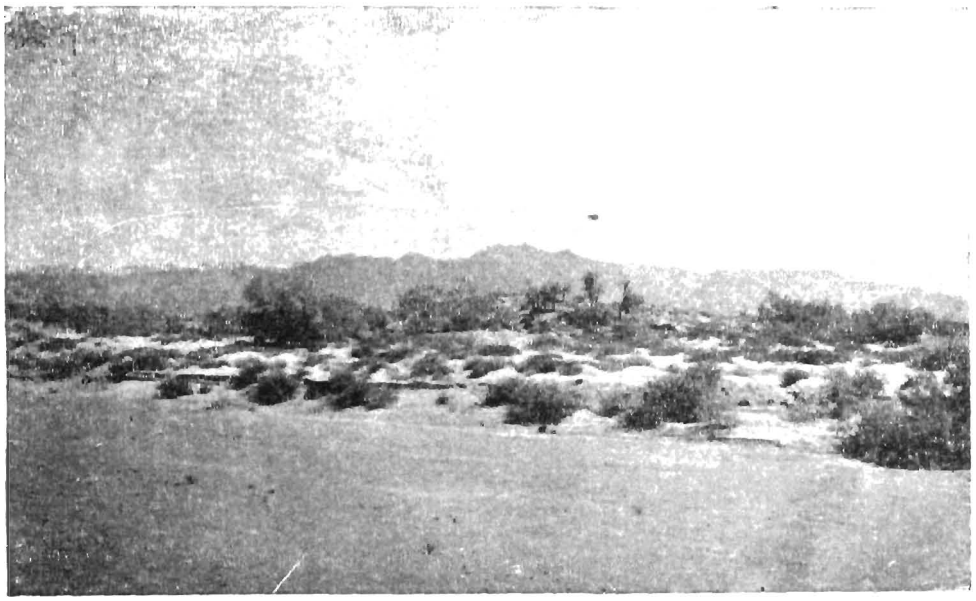


Plate 28.—*A silt rek covered with vegetation on the banks of a water-course in Kulanch* : February, 1936. The hills in the distance are the Talar Range forming the northern boundary of Kulanch. Breeding is known to occur in such reks in years of rainfall.

move would be of significance. It was felt, therefore, that a fully equipped meteorological station should be started on the actual spot of locust observation work on the Pasni area. At the commencement of the work, the equipment was limited to the indispensable minimum. The full set of instruments was installed in 1936 in a meteorological area located on the top of a low sand-dune (see Pl. 30), where they were arranged according to a plan supplied from Poona.

(a) *Pasni.* The following were the instruments in use at the meteorological area at the Pasni station.

I. *Stevenson Screen—No.* 1

1. *Air temperature*

Dry maximum thermometer.

Dry minimum thermometer.

N.B. - Well-tested standard instruments mostly from Negretti & Zambra were in use.

2. *Air relative humidity*

Dry and wet bulb thermometers.

In addition to taking the readings of the maximum and minimum temperatures, readings of temperatures were taken at 8 a.m. Local Time (*equivalent to 9-20 a.m. Indian Standard Time*).

In regard to air relative humidity, readings for maximum humidity were taken at about 6 a.m., and for minimum humidity at about 2 p.m. In addition, readings were recorded at 8 a.m. Local Time and 5 p.m. Standard Time.

II. *Stevenson Screen—No.* 2 (Large size)

1. Thermo-hygrograph (Records renewed once a week).
2. Wet maximum thermometer.
3. Wet minimum thermometer.
4. Piche Evaporimeter. (Records at 6 a.m. and 6 p.m.).

III. *Open air*

1. Maximum thermometer with open black bulb exposed at 2 in. height above soil surface.
2. Grass minimum thermometer at 2 in. height, above soil surface.
3. Maximum and minimum temperatures at 4 ft. height.

IV. *Evaporation* (Observations morning and evening).

1. Piche Evaporimeter in screen.
2. Piche Evaporimeter at 4 ft. height in the open.
3. Piche Evaporimeter at 4 in. height above soil surface in the open.

V. *Middle of bush*

1. Maximum and minimum temperature.
2. Maximum and minimum humidity determined with Assmann Psychrometer.

VI. *Soil temperature*

1. Maximum and minimum at soil surface with bulb horizontal and covered thinly by soil.
2. Maximum and minimum at 2 in. depth.
3. Maximum and minimum at 4 in. depth.

(Soil thermometers suited for the appropriate depth were permanently fixed in the soil and sight readings were taken at the particular times of day fixed after preliminary hourly observations, since maxima and minima are reached later at 2 inch and 4 inch depth than at the surface).

VII. *Soil moisture*

Percentage of moisture at (1) surface, (2) 2 inch depth and (3) 4 inch depth. Samples taken were weighed, and later on re-weighed after dry-drying them in a hot-water oven.

VIII. *Sun-shine record*

Sun-shine Recorder (Whipple-Casella) kept on a masonry pillar at 4 ft. height. (*Vide* Pl. 31).

IX. *Wind movements*

1. Standard Wind Vane to show the direction of the wind.
2. Standard Anemometer: recording velocity and mileage per day.

X. *Barometric pressure*

Recorded with an Aneroid barometer.

XI. *Rainfall*

Standard rain gauge.

XII. *Depth of soil moisture*

1. Depth of penetration of moisture in soil after rain.
2. Depth at which moist layers are reached in dry weather.

XIII. *Occurrence of fogs, dew, etc.*

XIV. *Record of general weather, clouds, storms, earthquakes, etc.*

(b) *Ambagh Station.* All the above instruments with the exception of (1) sun-shine recorder, (2) Thermohygrograph and (3) Grass-minimum and Black-bulb thermometers, were in use.

The observations taken at Ambagh were on the same lines as at Pasni.

(c) *Desert Outposts at Chachro, Nokh and Sardarshahr.* As these stations were under the charge of fieldmen, whose main duty was to carry out intensive survey work so as to keep a close watch over locust activities, meteorological observations were limited to the major macro-climatic data such as screen temperature and humidity, evaporation, rainfall, wind direction and force according to Beaufort scale, and weather notes. Since September 1936, self-recording hygrometers were installed at these stations but it was found they could not be relied upon as they required periodical adjustment and correction, which were beyond the capacity of fieldmen.

The following were the instruments installed at these outposts:

I. *Stevenson Screen*—with dry and wet bulb thermometers for measuring air humidity, and maximum and minimum thermometers for recording air temperatures. Records were taken also at 8 a.m. local time and 5 p.m. standard time for temperature and humidity.

II. *Stevenson Screen* (large size): to house the self-recording hygrometer and the Piche Evaporimeter.

III. *Standard raingauge*: to measure rainfall.

Whenever the Supervising Assistant visited the outpost he took other observations, such as soil temperature and bush data whenever needed.

All the instruments were arranged in a small area enclosed within a fence to prevent damage to the instruments by goats and cattle.

The instruments used for taking observations were in most cases standard ones recommended by the India Meteorological Department, as a rule accompanied by certified corrections. In most cases, they were tested by the Agricultural Meteorologist, Poona, before use at the various stations.

For recording the maximum and minimum temperatures, self-recording instruments were employed as far as possible. In regard to records of maximum and minimum humidity, and of maximum and minimum soil temperatures, where eye-reading instruments were employed, observations were taken at times of maxima and minima fixed for every

month on the basis of actual hourly observations. The times of maxima and minima were found to be very different for air humidity, for soil temperatures at different depths, for bush data etc.

In general, seasonal variation, *i.e.*, variation from month to month in the same year, has been found sufficient for all practical purposes in a study of locust ecology, and calculations of the daily means of various meteorological elements, such as maximum and minimum temperature, maximum and minimum humidity, evaporation, duration of sun-shine, etc., were being made every year, and included in the periodical progress reports of the different years. Though the inclusion of a full statement of the results of observations taken in inaccessible desert stations would have been very handy for purposes of reference and would, moreover, represent information of special interest from the meterological point of view, they have had to be left out owing to considerations of space. Instead, the statements of monthly data for a single year, *viz.*, 1938, have been appended to indicate the nature of the data collected. (*Vide* Statements IX to XIII).

The preparation of a statement of normals for the various items under observation at the different stations might have been useful, but was not attempted as even in the case of the oldest station, Pasni, only seven years' data were available, whereas it would not be possible to work out reliable normals with less than at least ten consecutive years.

Graphs showing the variation month to month of the average daily mean, the mean daily maximum and the mean daily minimum, the highest maximum and the lowest minimum in regard to (1) screen temperature, (2) screen humidity and (3) soil surface temperature have been prepared for seven consecutive years at Pasni (Text Fig. 7) and for four years at Sardarshahr (Text Fig. 8), which may serve to illustrate the peculiarities of the seasonal changes noticeable in the coastal areas subject to winter rainfall as contrasted with those of the inland desert areas subject to monsoon rainfall in Rajputana.

At Pasni, the temperature is comparatively warm in the winter months, though the minimum may occasionally touch the frost point during one of the cold waves, and during summer the thermometer rarely rises above 32°C. (90°F.), though during May or September-October, an occasional heat wave caused by a land-wind may raise the maximum to over 107°F. (42°C). The sand-surface temperature also runs closely parallel to the screen temperature, usually keeping about 15 to 20°C above the latter. As to humidity, the autumn and winter months are comparatively dry, especially October and November, but from May onwards, with the onset of the strong south-west wind from the sea, the humidity rises very high, as is clearly seen in Text Fig. 5 in which the humidity curves for seven years at Pasni have been superposed. Similarly Text Fig. 6 in which curves of monthly temperature changes at Pasni for seven years above been shown, clearly indicates that there is very little of variation from year to year at Pasni.

At Sardarshahr, which represents the conditions in the interior of the desert, fairly low minimum temperatures accompanied by fairly high humidity prevail during the winter months, but from March onwards temperatures rise rapidly and are accompanied by a steep fall of humidity, till the climax is reached in May and early June, when very high temperatures and extreme dryness of atmosphere are met with. With the advent of the monsoon by the end of June, conditions change. With the fall of rain, fairly high humidity prevails and the climate cools down. By the middle of September, the monsoon withdraws from the desert, when there is a secondary rise of temperature as well as a considerable fall of humidity, which continues till winter sets in by the end of November.

In studying the ecology of the locust, it was found that the ordinary macroclimatic observations made in the screen at a height of 4 ft. above the soil surface were not sufficient, but had to be supplemented by special data on the environment of the insect in the different stages of its life history each of which is set in its own peculiar horizon. The adult locusts usually frequent open spaces between bushes, while the hoppers are generally found in bushes and the eggs are deposited at a depth of four inches in the soil. All observations taken in special situations such as, 'in bushes', 'on soil surface' and 'the soil' are, thus, concerned with the eco-climate of the locust. Rainfall has been, however, found to be the most important factor in the life-economy of the locust in its natural breeding grounds, for without rain, there will not be sufficient soil moisture to permit of the occurrence of breeding, nor will there be an adequate amount of fresh vegetation on the ground to serve as food or shelter, and the general conditions may become so dry as to impose severe handicaps on the survival of the locust. On the other hand, given adequate rainfall it obtains all the desiderata for successful breeding and multiplication. Bio-climatographs to show graphically the effect of rainfall on breeding at different stations have been prepared and will be discussed at a later stage.

III. *Vegetation as a factor in locust ecology*

Vegetation is a factor of importance in locust ecology, as it functions not only as the main source of supply of food and water for the locust, but also provides it shelter from the elements and from enemies.

Though locusts have sometimes been found on stony or gravelly areas in the interior of Mekran with but scanty vegetation, and sometimes collected even from almost bare, open, clay plains, there is no doubt that such an occurrence is purely accidental, signifying possibly a halt in the course of migration. There is so little cover to the locust in these areas, that it hardly stays there long. On the other hand, locusts, especially the solitary ones, do not appear to like dense vegetation or forest areas, but apparently prefer low open scrub, especially such as is common in sandy areas.

There are, in the main, two types of vegetation in which locusts are usually met with, one of which is the 'Rek' type found in the Mekran coastal areas and the other, the 'Desert' type found in the interior of the Sind-Rajputana areas.

(a) *The 'Rek' type of vegetation.* A short account of the plant associations common on the rek areas of Mekran has already been given in the chapter on 'Vegetational Characteristics', but a description of the composition and distribution of the vegetation found on the Pasni rek area may be helpful in comprehending ecological problems at Pasni. (A list of the common flora of the Pasni reks is appended in Statement Ec. I).

Vegetation on the Pasni reks. While the large moving dunes are bare except for a few stray clumps of *Calotropis* and a few bushes of *Aerua*, the rest of the area consisting of low sand dunes separated from one another by shallow depressions, is mostly covered with scrub vegetation. Stray trees are also found, usually in the hollows between dunes, such as *Kahoor** (*Prosopis*), *Kunar* (*Zizyphus*), *chish* (*Acacia*) and *kaler* (*Capparis*).

During the greater part of the year, the cover consists of only the perennial type of vegetation. The bushes are usually separated from one another by open patches of sand, on which the adult locust is often found basking in the sun. After rains, however, a fairly dense growth of

*Please see list of Flora in Statement Ec. I for full scientific names.

Plate 29. *Bagort rck near Ambagh* : Showig the coastal dunes of shifting sand, partly covered with stunted Tamarick—1935. Depression in foreground is rather moist and covered with grass.

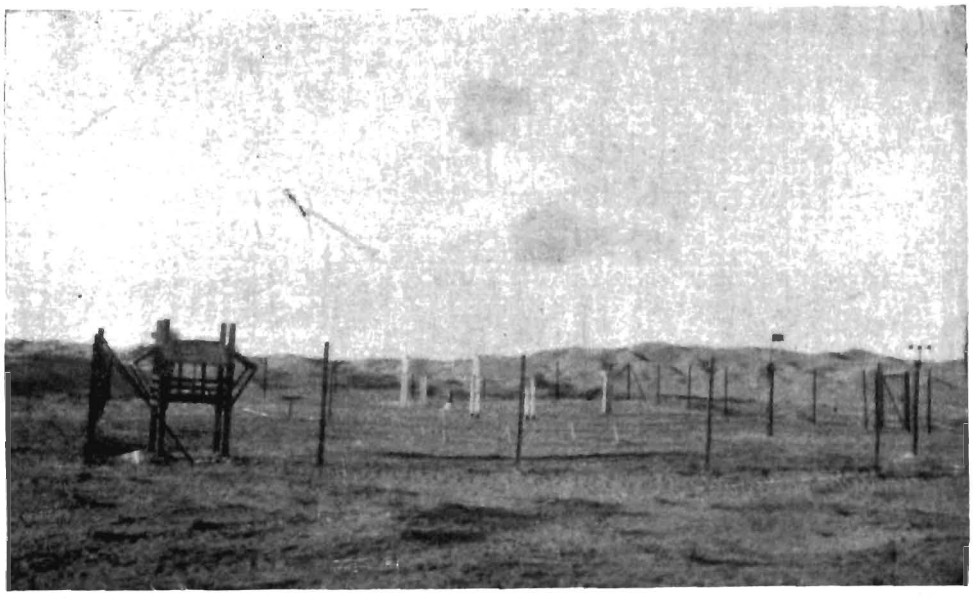


Plate 30.—*The meterological area at Pasni Field Station* : Located on top of low sand dune; enclosed with barbed-wire fence ; fitted with standard equipment including two screens with thermometers and a thermo-hygrograph, anemometer, wind-vane and sunshine recorder. A locally made sunshade is seen at the corner for keeping some of the instruments shaded.

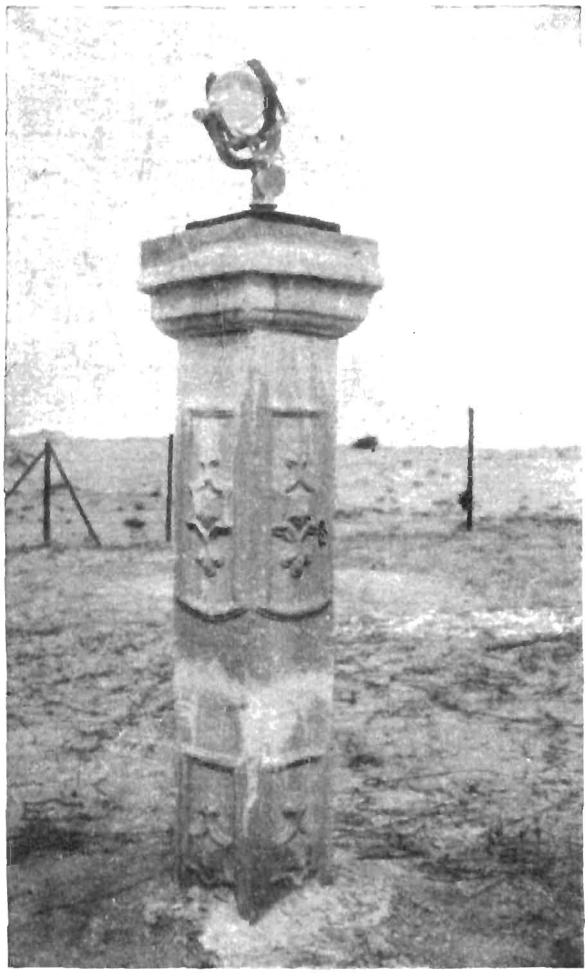


Plate 31.—*Sunshine Recorder (whipple-Casella)* : Mounted on a concrete masonry pillar and kept in the Pasni meteorological compound.

annuals springs up among and between the perennial bushes, especially along the base of the dunes so that the whole area presents a lovely green appearance while the annuals last.

The following are the perennials characteristic of the '*rek* areas' proper arranged in the order of their relative abundance: *Mazoung* (*Sphaerocoma*), *marrand* (*Heliotropium*), *tambo* (*Crotalaria*), *barshonk* (*Panicum*), *shalwardir* (*Asparagus*), *and balibur* (*Aerua*). *Kullichk* (*Cyperus*) is a common perennial with underground creeping stolons, which is present in most of the *reks*. *Jaduk* (*Lycium*) is also seen on some of the areas. With the fall of winter rains annuals begin to make their appearance on the *reks*: *Kuchakpad* (*Aizoon*), *sarang* (*Tribulus*), *nalako* (*Neurada*), *litko* (*Oldenlandia*), *danichk* (*Plantago*), *Halako* (*Launea*), *Puzzho marrand* (*Arnebia*), *sibar* (*Cenchrus*), etc. In the clayey soils at the bottom of the hollows between the sand-ridges, other plants are dominant: *Shimil* (*Indigofera*), *Kahurbahar* (*Astragalus*), *pimaluk* (*Asphodelus*), *shimsh* (*Trigonella*), *leyyo* (*Cressa*), *guragpad* (*Malva*), *hari-gosh* (*Emex*), etc. On the low-lying saltish areas, as in parts of the Maidan, salsolaceous plants such as *Reghit* (*Suaeda*), *mesk* (*Suaeda* sp.) *jhawad* (*Cornulaca*), *sorichk* (*Atriplex*). and *hashag* (*Salsola*), as well as coarse grasses such as *mund-kah* (*Heleochloa*) are common.

Among the various plants found on the Pasni *reks*, however, the dominant species in *mazoung* (*Sphaerocoma*), and *marrand* (*Heliotropium*) follows as a close second. In 1932, Karandikar while examining a part of the Pasni *reks* counted 560 plants in an area approximately 100 ft. by 100 ft., of which 367 (65 per cent.) were *mazoung* and 173, (31 per cent.) *marrand* and the rest 20 (4 per cent.), other species. In another case, he recorded 997 plants in an area (extent not specified) of which 653 (63·7 per cent.) were *mazoung*, 259 (29·8 per cent.) *marrand*, 57 (5·4 per cent.) *barshonk*, and 8 (1·4 per cent.) were *tambo*, *balibur* and *Jaduk*.

Roonwal carried out complete surveys of the *reks* of Pasni, to note the order of dominance of the various plants in the different parts of the *rek* area during 1936 and 1937 and in the case of one of the plant quadrats recorded by him there were 70 plants in an area 30 ft. by 30 ft. of which 6 were *marrand*, 5 *mazoung*, 3 *jaduk*, 1 *halako*, and 2 *zardphul*, besides numerous sprouts of *Kullichk* (*Cyperus*) (Quadrat I). In another case, also 30 ft. by 30 ft. out of 131 plants, 24 were *marrand*, 70 *mazoung*, 28 *shirwal*, 3 *barshonk*, 1 *tambo*, 2 *gandhil* and 3 *shalwardir*, besides a fair number of *kullichk* (Quadrat II). It was, however, evident that on account of the failure of rainfall in the winter of 1936-37, many of the plants in the plant quadrats were found to have been stiffed by drift sand by the middle of 1937.

From the details of the counts given above, it is obvious that there is a great deal of local variation in regard to the proportion of the different components of the *rek* vegetation in particular parts. For instance on the Sadi *rek*, the Hadzai *rek* and the Ekmach *rek*, *marrand* is predominant over *mazoung*. Again, in parts of the Adasti *rek* area and in the Gurrani-Rahmat Chah areas, *shalwardir* is present in fairly large numbers in places, while in others, *tambo* is prominent. *Tambo* is also found in fair abundance in the Chur *rek* area. Clumps of *barshonk* (*Panicum*) are seen in small numbers in most parts of the *rek* areas but are fairly abundant in parts of the Gurrani area. *Balibur* is more or less confined to parts of Rahmat-Chah, Sanjar and Deghan areas, while *kharzan* is to be seen only in the hollows of parts of the Adasti *rek*. The areas of abundance of the different *rek plants* has been shown in the attached map of the Pasni *rek* area (*vide* Text Fig. 4).

It is presumed that the relative dominance of particular plants in particular parts of the reks is dependent on the suitability of the latter to their ecological needs. An examination, for instance, of the root-system of *marrand* and *mazoung* revealed that *marrand* possesses a single, but fairly stout tap-root, which usually penetrates to a depth of 3 ft. to 4 ft. of the sandy soil and taps the moisture available within a radius of 4 ft. to 5 ft. at that depth. The root, moreover, is thick and fleshy and its internal structure is obviously adopted for storing water. On the other hand, *mazoung* has several thin branching roots, which also penetrate to a depth of over 3 ft. Adopted as these two plants are for growth in deep sand they would obviously be a mis-fit in hard clay soils. *Balibur* is also possessed of a root-system adapted for soft sand and often flourishes on almost bare dunes. A study of the adaptations of the various rek plants to their special habitat may yield very interesting results and is worth pursuing.

Vegetation on other rek areas.—The vegetation found on the other reks of the western part of the Mekran coast is exactly similar to that of Pasni, though there is a good deal of variation in regard to the dominance of the following species in different situations. In the Somniani-Ambagh-Naka Kharrari reks, *marrand* is comparatively scarce and its place is taken by *Kharzan*. As these areas, moreover, fall within the influence of monsoon rainfall, the vegetation is at its best in summer. *Balibur* exhibits a more luxuriant growth in places, as at Naka-Kharrari and to new elements such as *wanjo* (*Indigofera cordifolia*), which are common in the Sind desert, are met with here.

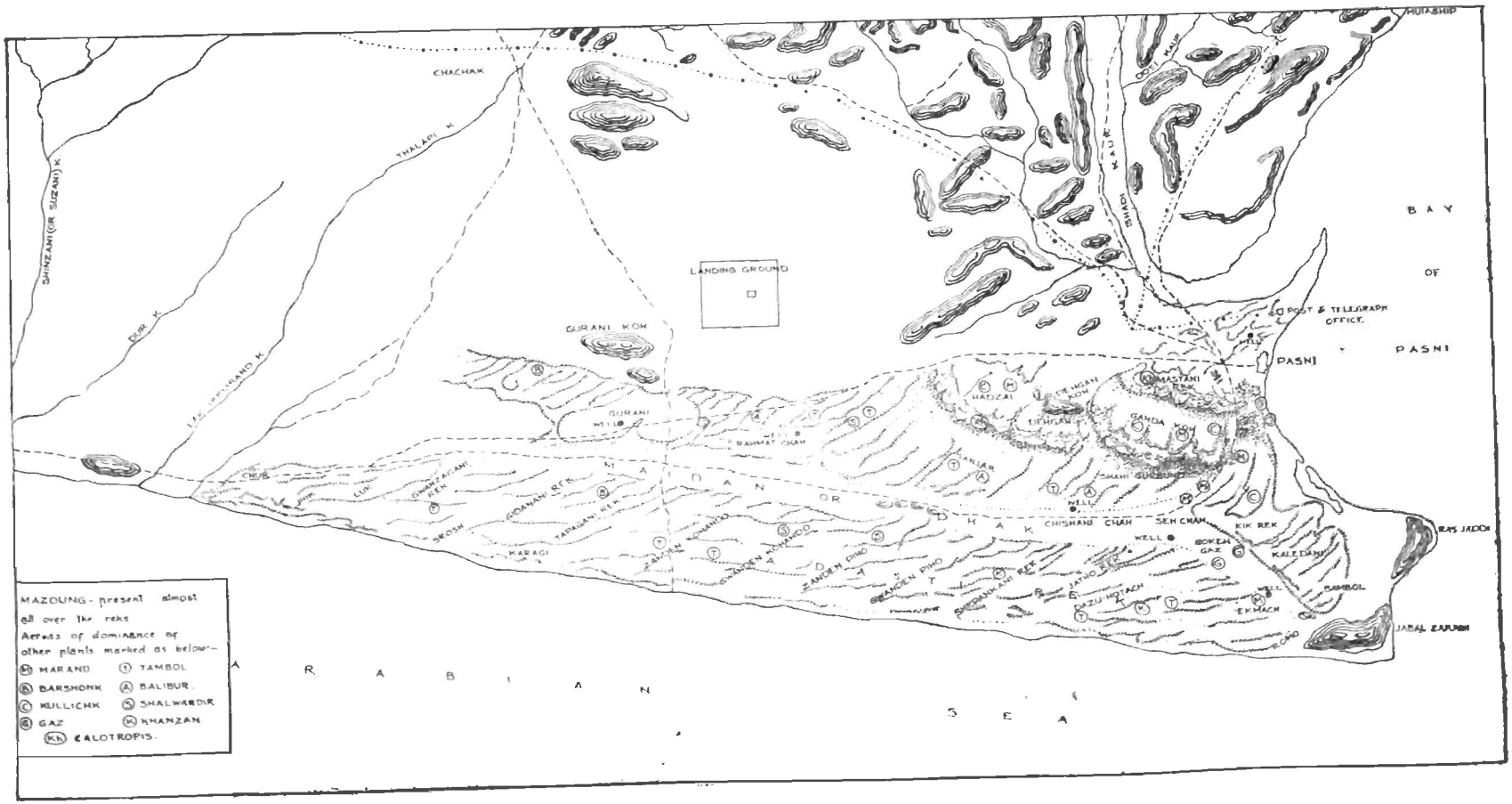
Vegetation on the reks of the interior of Mekran.—These reks are mostly formed of silt or fine sand shifted from the alluvium of the valleys, and the vegetation found on them is markedly different from that of the coastal reks. *Mazoung* is totally absent, and *marrand* is sparingly represented. *Barshonk* (*Panicum turgidum*) is present in most places and *balibur* is also seen sometimes. *Patto* (*Calligonum polygonoides*), *Hashag* (*Salsola foetida*), and *Traht* (*Holoxylon salicornicum*) may also be present. Kapocham (*Chrozophora verbascifolia*), *lantu* (*Taverniera nummularia*) and *shinz* (*Alhagi camelorum*) are also found in some places.

(b) *The 'Desert' type of vegetation.*—As contrasted with the 'reks' of Mekran, the 'desert' areas are situated far from the influence of the sea, but receive comparatively more rainfall. Consequently, the vegetation found in the desert is very different from that of the '*reks*'. While the vegetation of the '*reks*' may be classified as 'Desert Scrub' that of the Sind-Rajputana area may be termed 'Desert Scrub—Desert Grass Savannah', with the addition of an '*Acacia*' element in the southern parts. A fairly full description of the vegetation of the desert areas has been given in an earlier chapter.

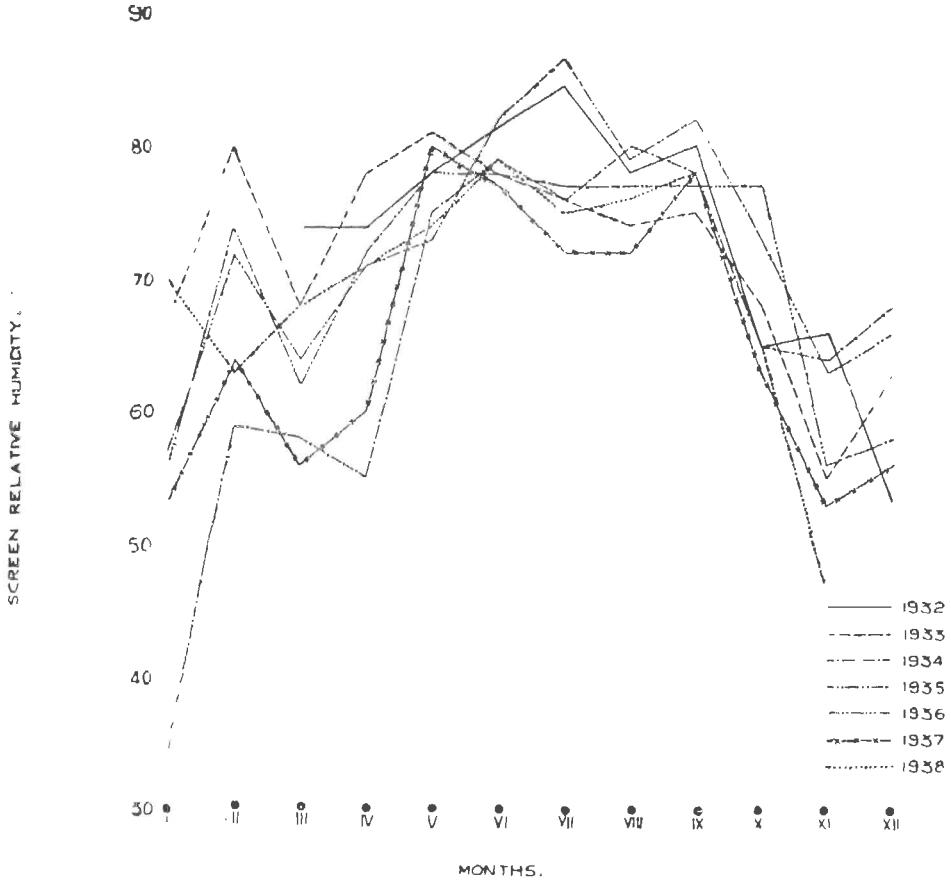
Compared with the reks, the scrub is generally taller in the desert areas and in the southern desert it attains the stature of high bush owing to the occurrence of various species of *Acacia* and of all plants such as species of *Zizyphus*, *Grewia*, *Cordia*, *Gymnosporia*, *Clerodendron Salvadora* and *Capparis*. Moreover, *phog* (*Calligonum polygonoides*) forms a fairly dense cover over large areas of the dune areas and *murali* (*Lycium europaeum*) and *khip* (*Leptadenia spartium*) attain a fairly large size in many places. Trees such as *khejri* (*Prosopis spicigera*) and *rohida* (*Tecomella undulata*) are also fairly common in the hollows. In the northern areas, the north western parts comprised of the Shahgarh area of Jaisalmer and the neighbouring parts of Khairpur and Bahawalpur States, form the driest and barest parts of the desert owing to low

Text Figure 4]

MAP OF PASNI REK AREA AND ITS NEIGHBOURHOOD.



Text Figure 5]



GRAPH SHOWING THE VARIATIONS IN THE MEAN MONTHLY RELATIVE HUMIDITY IN SCREEN FOR THE YEARS 1932-1938 AT PASNI

rainfall. The areas of north-east Jaisalmer and western Bikaner are characterized by high dunes covered with low scrub, usually clumps of *murt* (*Panicum turgidum*) *and siwan* (*Elionurus hirsutus*). *chag* or *siniya* (*Crotalaria*), *booh* (*Aerua tomentosa*), *murali* (*Lycium*) and *khip* (*Leptadenia*). *Phog* (*Calligonum*) is common in some places, and in others *lana* (*Haloxylon salicornicum*), both of which cover large areas of the desert. In the north eastern parts, the dunes are, except for clumps of grass and stray bushes of *booh* (*Aerua*) and *maso* (*Tephrosia*), and for creeping stolons of *Cyperus,* more or less bereft of vegetation.

During dry weather, much of the ground between the larger bushes is bare, and except where *Chag* (*Crotalaria*) *and Booh* (*Aerua*) bushes are present, there is little of cover for locusts which circumstance in combination with the prevalence of high temperature and low humidity may be presumed to cause them to leave the area. On the other hand consequent on the burst of the monsoon, numerous annuals spring up all over the desert, and provide a dense cover of vegetation between the larger bushes. The most common of the annuals are *Bharat* (*Cenchrus catharticus*) *and lampdo* (*Aristida* spp.) among grasses, and *wekra* or *bekkar* (*Indigofera cordifolia*), *vishani* (*Tephrosia hookeriana*), *trikandi* (*Tribulus*), *sanawri* (*Boerhavia diffusa*), *sareli* (*Gisekia pharnacioides*) *haran chapari* (*Farsetia jacquemontii*), and *phel* (*Dipterygium*).

With the object of studying the density of vegetation, areas 30 ft. square were marked out in the desert and the exact position and number of the different species of plants within the quadrat were charted. A *Lana* area between Nokh and Bikaner was examined on the 1 April 1935, and it was found that out of 26 plants found within 30ft. square, there were 15 *Lana*, 3 clumps of *Bharut* grass, 5 of *gandhil* grass, 1 of *murt* grass, and one of bush of *chag*, besides which there were numerous dry stems of Aristida grass (Quadrat III). In another case, examined at Bikampur on the 4 April, 1935, out of 15 plants counted within 30 ft. square, 25 were *chag*, 15 *murt* clumps, 3 *phel*, one *lana* and one *phog* bush covering about 7 ft. by 5 ft. There were besides several patches of gandhil grass. At the end of the monsoon, a plant quadrat examination of an area 30 ft. square was made at Nokh on 9th November, 1935, when it was found that, out of a total of 56 plants, 36 were *booh*, 14 *Chag*, 3 *'ak'* (*Calotropis*) and 3 *akhro* (*Melothria*), and there were besides, large numbers of *bharut* and *gandhil* interspersed among and between the bush vegetation, (Quadrat IV). At Chachro an examination of three different areas was made during the monsoon of 1935 and charts of the vegetation found within plots 30 ft. square recorded. In a quadrat examined on 19 July, out of 89 plants, there was one large *bavuri* bush (*Acacia jacquemontii*) covering a space of 9 ft. by 7 ft., two *phog* bushes of which one was 6 ft. by 6 ft., one Calotropis bush, 7 *murt* clumps, 20 *booh* and 3 *sinia* (*Crotalaria*) bushes, and 15 *vishani* (*Tephrosia*) and 40 *wekra* (*Indigofera*) plants, (Quadrat V). In a second case, charted on 22nd August, out of 29 bushes, one was a large *phog* bush 7ft. by 4ft., one a *bavuri* bush 5 ft. by 3 ft., one a *bordi* (*Zizyphus*) bush 7 ft. by 3 ft., one small Calotropis bush, 18 *booh* bushes, 5 large *murt* and one *siwan* (*Elionurus*) clumps and one large patch of *bakhra* (*Tribulus*), besides which there was a dense growth of annuals mostly *wekra, bharut* and *Aristida* (Quadrat VI). In a third quadrat recorded on 21 September, out of 150 plants, 98 were *vishani*, 38 were *booh*, one fairly large *phog* bush, 2 Calotropis, 1 *murt* clump and 7 *akhdo* (*Melothria*), besides large numbers of grasses, (Quadrat VII) (Text Fig. 9).

It is thus seen that there is good cover over the ground during the rains owing to the growth of annuals, but with the drying up and disappearance of the ephemeral vegetation, the desert becomes exposed

as the permanent bushes are generally too tall and too far apart from one another. It is only where *booh*, or *lana* is dominant or where grass slumps—*siwan* or *murt*—are the chief components that the desert locus can get some shelter in the dry season. On the other hand, the bushes on the reks are rarely more than 3 ft. apart and most of them are low and dense and give excellent protection to the locust.

IV. *The influence of other animals on locust ecology*

The locust is a plant feeder, and consequently its relationship with other animals is restricted to that of (1) a prey of predatory animals or a host of parasites, and (2) a competitor to similar animals feeding on the same food-plants.

Under the second category might be included other locusts or grass-hoppers found on the desert vegetation, as also large animals such as camels and goats grazing in the desert. Such a competition has not in general been noticed anywhere, for spaces in the natural habitat of the locust are so vast that such a contingency is not likely to arise unless the locust happens to be in the swarming phase.

As to parasites and predators, a fairly large number have been noted in the course of locust surveys. As, however, the solitary phase locusts occur in relatively small numbers, observations on natural enemies are, on the whole, comparatively few. As a rule, both in the hopper and the adult stage, the solitary locust is protectively coloured, and it is only when it makes an abrupt movement that it attracts the attention of its enemies. For instance, it is only when the solitary locust flies up under pursuit that it is taken by predatory birds. When swarms are prevalent, on the other hand, their presence is so evident that they become the focus of attack by a host of enemies. In general, the predators that attack locusts found in swarms will also attack individuals of the solitary phase, whenever they find them. All animals observed in the tole of parasites or predators on the desert locust—whether in the solitary or in the gregarious phase—are listed below, and a few notes on their distribution and habits have been added as far as available.

Natural enemies of the Desert Locust in the Indian region

1. *Vertebrates.* (i) *Mammals—Carnivora.* Whenever locust swarms are sighted, it is well-known that various animals, such as cats, dogs, jackals and foxes will gorge themselves on locusts. Even monkeys are not averse to a feed on locusts when they can capture them.

Cheiroptera (Bats). It is also certain that many of the bats capture locusts when on the wing. In November, 1937 the writer found a heap of wings and hind-legs of the migratory locust (*Locusta migratoria*) on the floor of a large hollow in an old *mahua* tree in the Mehsana district of Baroda State, which had evidently been captured and eaten by bats [Rao and Bhatia]. At the close of October, 1940, a small swarm of the desert locust was reported to have passed through the neighbourhood of Delhi, and at that time, several stray fore and hind wings of pink adults were collected on the steps of the Secretariat Buildings by Dr. W. Burns, Agricultural Commissioner to the Government of India, and subsequently, the writer found numerous specimens of cut tegmina, wings and hind legs of the locust, as well as a hind-leg of *Anacridium egyptium* on the roof-tops of the Secretariat on 1 November. An examination of the wings and legs collected showed marks of small sharp teeth at the cut edge indicating that they had been attacked by some of the smaller bats, such as species of *Vesperugo, Vespertilio* or *Bhinopoma* during twilight flight. The Indian Vampire bat—*Lyroderma lyra* Geoff.— is also known to attack some of the larger grass-hoppers and crickets.

(ii) *Birds.—Corvidae.* Crows and ravens are known to feed on locust adults and hoppers during outbreaks.

Timaliidae: *Argya caudata caudata* Dum. The common Babbler, Leilei Leilell (Sind) has been observed catching young, newly fledged adult locusts at Chachro. Most of the babblers would seem to have similar habits.

Pyenontidae: *Molpastes leucogenys*. The 'bulbul', Hudia (Sind), is common in the desert and is partly insectivorous.

Laniidae. The Shrikes—*Lanius excubitor lahtora*, "Malhar" (Sind). *Sagun-chidia* (Punjab)—the Indian Grey Shrike, and *Lanius cristatus isabellinus*—the Pale-brown Shrike have been noted to attack adult locusts in the rek and desert areas.

Dicruridae. The sub-species of *Dicrurus macrocercus* are common in the desert and have been known to attack the locust on the wing. 'Kala Chidia, (Desert) 'Kolsa' (North Bombay), (The King Crow or Black Drongo). Mason and Lefroy [1912] have recorded it as attacking *Patanga*—Bombay Locust.

Sturdidae. -The common Mynah *Acridotheres tristis tristis* L. '*Khabbar*' (Sind), '*Lalee*' or '*Ghursila*' (Punjab) is common in the desert areas and is well-known for its special taste for grass-hoppers and their young ones. The Rosy Pastor (*Pastor roseus* L.) known as '*Gulabi Tiliar*' in Punjab, '*Sar*' or '*Sarak*' in Pashtu and Persian areas, '*Wahiya*' in Lasbela and Sind, and *Bhayya* in the Rajputana areas, breeds in Russian Turkistan and eastern Europe in early summer and migrates south soon after. It begins to appear in north-west India in July and is to be seen in large flocks all over India in autumn and winter. The attacks of the Rosy Pastor (also known by the name of 'Jowari Bird' owing to the damage caused by them on the jowar ear-heads)—on flying swarms of locusts are well known to cultivators. Stuart Baker [1926] writes :'When there are locust invasions, the 'Jowari Birds' kill and eat an incredible number and are one of the most important factors in dealing with them.' *Sturnus vulgaris humii* (Brooks)—the Himalayan Starling is also common in Sind and Baluchistan and feeds on locusts and grass-hoppers.

Coraciidae: *Coracias garrula semenowi*. The Kashmir Roller and *Coracias benghalensis benghalensis*—the Indian Roller—have both been found in Baluchistan and the Rajputana desert areas. In numerous cases the Roller has been found attacking the adult locust during flight. It is well-known in most places under various local names: '*Kangashk*' (Baluchistan), *Nil-Kanth* (Punjab), '*Lil-tans*' (Sadulpur), '*Suto*' (Bikaner).

Meropidae—The Bee Eaters. *Merops orientalis orientalis* and *Merops orientalis biludschicus* are common in the desert and rek areas and have been observed to capture flying locust individuals at times. Local names: '*Darkoon*' (Pasni), '*Piyal*' (Rajputana).

Upupidae. The Hoopoe is common in many places and according to Mason and Lefroy [1912], grass-hoppers and crickets form a great part of the diet of adults and the young ones. *Upupa epops* L. is common in Baluchistan and *Upupa indica* in the Rajputana area. Known as 'Murgh-i-Suleiman' at Pasni.

Falconidae. Remains of four adult locusts (solitary phase) were found in the stomach of a specimen of *Circus macrourus*, the Pale Harrier shot in the Kolwa valley in September 1932. Many of the smaller falcons, such as Hobbies, Merlins and Kestrels, also subsist to a great extent on grass-hoppers (especially locusts) [Mason and Lefroy, 1912]. According to Stuart Baker [1926], *Butastur teesa*—the White-eyed Buzzard

Eagle—"Occasionally takes any large insect, being very partial to large grass-hoppers or locusts, which it seizes on the wing." The various kites: *Haliastur indus, Milvus migrans govinda,* and *Milvus migrans lineatus,* would appear to attack swarms of locusts. Regarding the two species of Milvus, Stuart Baker remarks, "They collect in large flocks and follow flights of locusts for many miles, gorging to repletion on these".

Otididae: *Eupodotis edwardsi*—the Great Indian Bustard—feeds largely on grass-hoppers and locusts.

Ciconiidae: *Ciconia alba*—the White Stork—attacks locusts and grass-hoppers when they occur in large numbers.

(ii) *Reptiles*—(a) *Lacertilia* (*Lizards*) Green hoppers were found in the stomach of three lizards found at Pasni (1) *Acanthodactylus cantoris cantoris* (Lacertidae), (2) *Agama agilis* (Agamidae), and (3) *Eumeces schneideri* (Scincidae). *Acanthodactylus cantoris cantoris* is common in the Rajputana desert and large adults of this lizard have been more than once observed attempting to catch adult locusts. *Agama minor*, *Calotes versicolor* and *Varanus griseus* are present in some numbers in the Sind-Rajputana area and as they are of fairly large size, they may be expected to feed on good numbers of locusts, when swarms are about.

(b) *Ophidia* (*Snakes*). In one instance, a locust adult was found in the stomach of the Sand Viper—*Echis carinata*—at Akara near Gwadar. Various species of *Zamenis*, *Psammophis*. *Tropidonotus* and *Dipsadomorphus* are common in the desert, and it is possible that they may take locusts when they are abundant.

(iv) *Anura* (Frogs and Toads)—*Bufo viridis* and *Rana* spp. are found in some parts of the locust habitat and may feed on the hoppers to a certain extent.

II. *Invertebrates*.

(a) *Nematoda*. Many instances of Nematode worms attacking locust egg-masses under conditions of water-logging in cages were noted. Presumably they are saprophagous in their habits and feed on the dead eggs.

(b) *Arachnida*: *Spiders*. Certain Spiders (unidentified) have been found at Pasni feeding on the young hoppers entangled in webs spread among rek bushes.

Galeodidae: Species of *Galedoes* and *Galeodellus* are common in the desert and it is possible that they may be predatory on the locust hoppers.

Mites.—1. Young mites of red colour are commonly found on the wings of locust adults and sometimes also on the bodies of hoppers. They do not seem, however, to do any appreciable harm to their hosts. They are presumed to be the young ones of *Trombidium grandissimum*, which is generally found in large numbers on the ground soon after the first heavy rain in the desert.

2. *Tyroglyphid*.—This is a mite which has been often found on the solitary phase locusts. Both the larvae and the adults crowd together on the wings and the thoracic segments and often occur in enormous numbers. Their bright white moult skins are found sticking to the wings and body of the locust in dense and conspicuous clusters, by which this mite can be easily recognized,

(c) *Insecta*:—*Coleoptera*: *Carabidae*: *Scarites sulcatus* in a large black beetle that was found predaceous on gregarious hoppers at Dalbandin in May 1931.

Histeridae: *Saprinus ornatus* is a small beetle whose grubs (resembling Carabid larvae in general form) were found feeding on eggs laid in the bed of Lora Zafran near Kuchlak in Quetta Tehsil (Baluchistan) in May 1931. The adult beetles have since been collected from many places in Baluchistan.

Hymenoptera: *Sphegidae*: A large blackish Sphegid, presumably *Chlorion regalis* Sm. was observed pursuing an adult solitary locust on the wing on the forenoon of 30 May 1936 on the Pasni rek. The locust, however, made every attempt to elude pursuit by zig-zagging in the air, by flying high one moment and by dropping to the ground level at another. The chase lasted nearly five minutes, but eventually it looked as if the locust had made good its escape. Although no other instance of a similar attack was noticed, it is not unlikely that this Sphegid is in the habit of capturing large grass-hoppers of the size of the desert locust for providing them as larder for its young. In this connection, mention may be made of the interesting observations recorded by Williams [1933] at Amani in East Africa on the appearance of *Sphex aegyptiacus* in large numbers between 29 January and 7 February, 1929, along with locust swarms, and of their digging burrows in the ground into which the paralysed adult locusts were, subsequently, dragged.

Formicidae: Workers of *Myrmecocystus viaticus* and *Monomorium salomonis indicum* have been found attacking young hoppers at Pasni.

Diptera: *Calliphoridae*: *Agria latifrons* Fln. has been reared from flying swarms collected at Quetta in June, 1931. There are numerous records of 'maggot' infestation among locusts in past invasions, the maggots being referred to as 'kirm' in Baluchistan and as 'lat' in Rajputana.

As specimens of flies reared in past invasions do not appear to have been determined and recorded, it is not possible to say if any other species of Calliphorid similarly attacks flying swarms in India.

Wohlfahrtia nuba Wied., has been reared from hopers and adults collected in the Mekran rek areas, and *Wohlfahrtia trina* Wied, from locusts in the Ambagh area in 1938. There are no observations, however, on any actual infestation by these flies in the field. In one case, it was found that infection had taken place in an insect store-box containing killed locusts, which had been pinned into the corklined bottom by the fieldman and had been kept exposed to sunlight to accelerate their drying. A week later large numbers of maggots were found crawling at the bottom of the box. In this connection, the observations of Van Schalkwijk [1939] on the status of *Wohlfahrtia euvittata* Vill. as a parasite of the Brown Locust in South Africa are of much interest. After much careful experimentation, he came to the conclusion that individuals of *W. euvittata* can live both as scavengers on dead locusts or dead animal matter and as parasites on live locusts. He also found that hoppers were attacked only when moulting or when sick or wounded and that only phases *congregans* and *gregaria* were attacked, not *solitaria*. Further information is, therefore, needed on the habits of the Indian species of *Wohlfahrtia* before any definite opinion can be expressed on their economic status.

Asilidae: Asilid flies have been noticed attacking young hoppers at Pasni, and at various places in the Rajputana desert. The species from Pasni were determined at the British Museum to belong to the genera

Stenopogon and *Philodicus*. A fly collected at Chachro was determined to be near *Apoclea femoralis* Wied. The flies also victimized young hoppers of other Acrididae.

(d) *Chilopoda*.—The Centipede—*Scolopendra morsitans* L. has been found to attack locusts kept in cages at the Pasni station. In view of the fact that this species is extremely abundant on the reks, it is not unlikely that similar attacks may be of common occurrence in nature.

On the whole, however, the desert locust does not appear to have any natural enemies of a serious character in the Indian area of its habitat with the exception, possibly, of birds in general. (A list of some of the Fauna collected or noted on the Pasni Reks is appended for reference in Statement Ec. II).

V. *The role of soils in locust economy.*

The desert locust shows a marked preference for sandy soils covered with low bush vegetation, and most of the favoured areas of its habitat, such as the 'reks' of Mekran and the 'desert' areas of Sind and Rajputana, are predominantly of a sandy character. Egg-laying, however, takes place only after sufficient rain has fallen so as to ensure the existence of an optimum amount of soil-moisture for egg-development.

Locusts of the solitary phase are known to lay eggs at times also in the interior of Mekran and in the hill valleys of Upper Baluchistan. The soils of these areas, however, are mostly light loams, though light accumulations of fine blown sand in the form of low mounds are also noticeable in some places. As it was a rather remarkable circumstance that most of the *outbreak centres* of the locust that were examined by the locust survey staff in Mekran and Lasbela were found to have been associated with such light or sandy loams, a mechanical analysis of soils collected from 'reks' and from some of the interior valleys, was carried out at the laboratories of the Imperial Agricultural Chemist, New Delhi with the following results:—

Particulars of soil	Clay	Silt	Fine Sand	Coarse sand
	percent	percent	percent	percent
REK SOILS.—				
Ambagh Reks :—				
Hard Sand	4·6	6·6	2·6	86·2
Loose Sand	1·2	2·4	2·0	94·4
SOILS OF DESERT TYPE—				
Bagar area (between Naka-Kharrari and Hab-Chowki).	6·8	9·6	6·6	77·0
LOAM SOILS OF THE INTERIOR—				
Cultivated loam near Quetta . . .	15·2	25·4	33·4	26·0
Cultivated soils in Kachhi Area—				
Loam at Gandhawa	17·2	31·2	24·0	27·6
Loam at Bhag	23·0	48·0	17·8	10·6
Clay loam at Bhag	31·8	37·2	27·2	4·0

Maxwell-Darling's figures of Mechanical Analysis of similar areas in Sudan

1	2	3	4	5
'Goz' areas in Kordofan —				
1. Cultivated Goz	3·9	2·0	23·0	71·2
2. Cultivated Goz	3·2	0·2	15·8	80·7
3. Fallow Goz	3·2	2·6	19·0	75·2
'Sisa' area in bottom of Wadi . . .	36·8	8·3	30·8	23·9

From the data tabulated, it may be seen that in the 'rek' and 'desert' type of soils, as well as in the 'Goz' type of Maxwell-Darling, there is a greater percentage of coarse sand as compared with the loam types found in the interior of Mekran and Upper Baluchistan. In the latter, the different components, such as coarse sand, fine sand, silt and clay are more or less in equal proportions, as is the case with the 'sisa' type of Maxwell-Darling [1934]. In the case of the clay loam found at Bhag, the proportion of clay and silt is very much higher than the sand component.

In the reks themselves, the hard sand type met with in the hardened soil of old dunes found at Pasni and in the desert, the proportion of clay and silt is greater than in the looser type, which is probably due to their infiltration into sand along with rain-water.

The main difference between the sandy soils containing a large proportion of coarse and fine sand and the light loams in which silt and clay are in larger proportion lies in the fact that the latter type is capable of retaining moisture for a longer period of time than the former. In the sandy rek or desert soils, the effect of a heavy soaking caused by a fall of about 2 in. of rain may, from the point of view of oviposition, not last more than about three to four weeks, whereas in loamy soils, the requisite amount of moisture may be present for a longer period. It is possible that this circumstance may be one of the factors that lead to crowded egg-laying in the interior valleys. In the spring of 1937, for instance, egg-laying and hatching continued in certain favourable localities in the loam soils of the Kachhi area for about four months after the last rainfall. On the other hand, in sandy areas the influence of rainfall in regard to breeding does not usually extend much over six weeks.

B. The effect of various ecological factors on the biotic potential of the locust

It was with the object of making an exact determination of the part played by different environmental factors on the life-history of the solitary phase locust in its natural breeding grounds that ecological studies were started at Pasni in 1932 and subsequently at other stations.

At the period when investigations were begun, however, the generally prevailing view was that all solitary locusts led a sedentary life within their respective areas in Baluchistan or Rajputana, and that by keeping a close watch on the degree of density of locust population therein it should be possible to measure the influence of various ecological factors on the multiplication of the locust. It was also believed that by a weakening of the environmental resistance, an abnormal increase in numbers would be

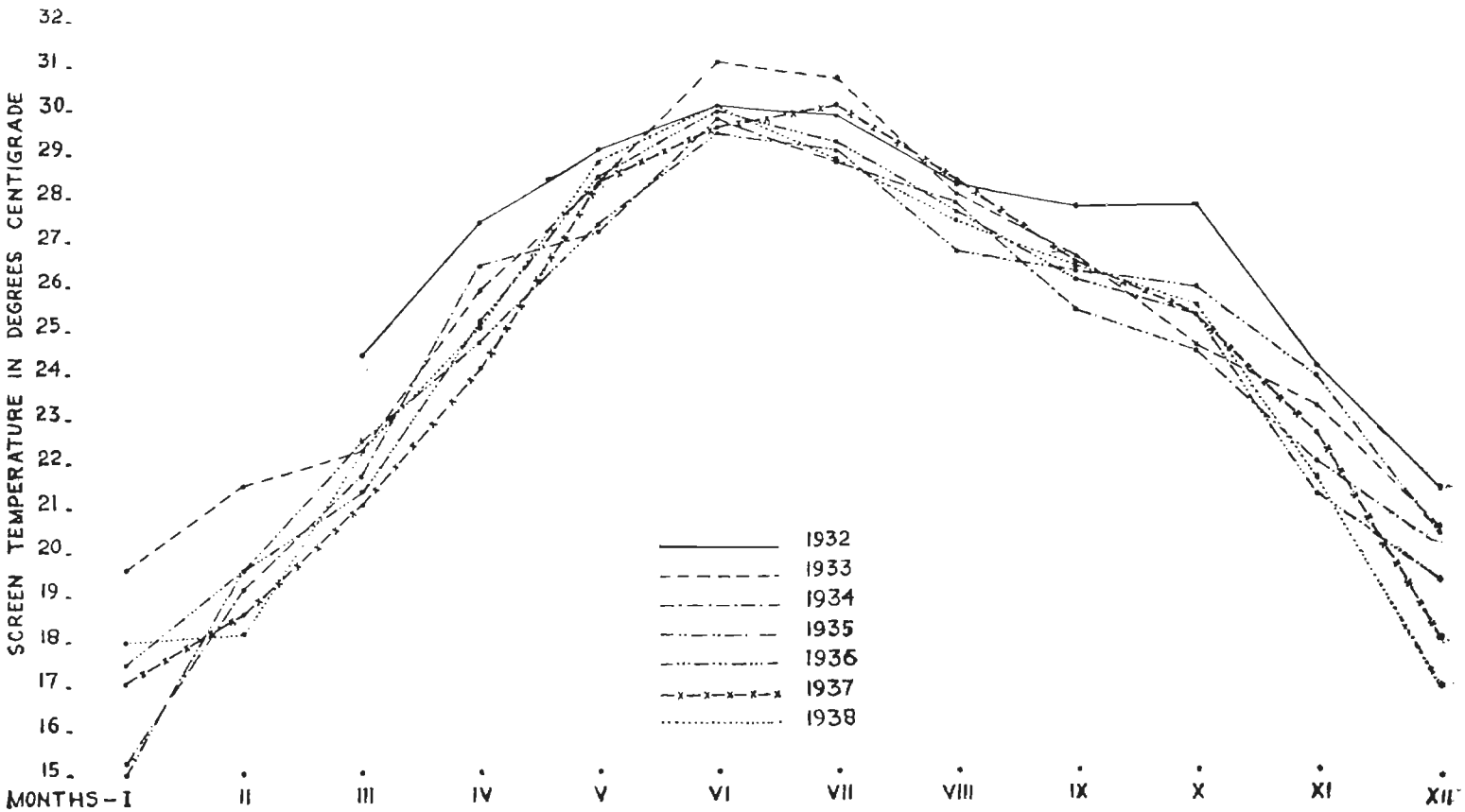
brought about, leading to a general migration of the insect into distant areas. With the progress of the investigations, however, it became evident that even the solitary phase individuals were in the habit of migrating regularly from the winter rain area to those of summer rainfall, and *vice versa* just as swarms of locusts do, so that the additional factor of migration of the solitary phase had also to be taken into account in ecological studies, as there was the possibility of the locust population of the area under observation being affected by an immigration from another distant breeding ground, as also at other times by an emigration out of the area.

In the course of the ecological work carried out at the different stations, all the various biological activities of the locust were kept under close observation, notes being taken as far as possible of the exact meteorological conditions associated with them. In addition to observations carried out in the field, locusts were kept in cages under semi-natural conditions at the various stations for checking and confirming the field results. Some of the results of these experiments have already been described in the preceding chapter.

In considering the effect of the various environmental factors, such as climate, vegetation and natural enemies, on the biotic potential of the locust, it should be kept in mind that in many cases, these factors operate not individually, but as an ecological complex, acting and reacting on one another, so that very often it is not possible to trace the effect to any particular individual factor. For instance, in the absence of rainfall, conditions of high temperature and desiccation, associated with dried up vegetation, would prevail, which would be unfavourable either for the breeding of the locust or for the existence of its natural enemies, whereas with the occurrence of rainfall optimum conditions of temperature and humidity, as well as of soil-moisture, would be brought into existence, and dense lush vegetation would spring up, all of which would be extremely favourable for locust breeding and multiplication. At the same time, the natural enemies of the locust would also meet with optimum conditions for their activity.

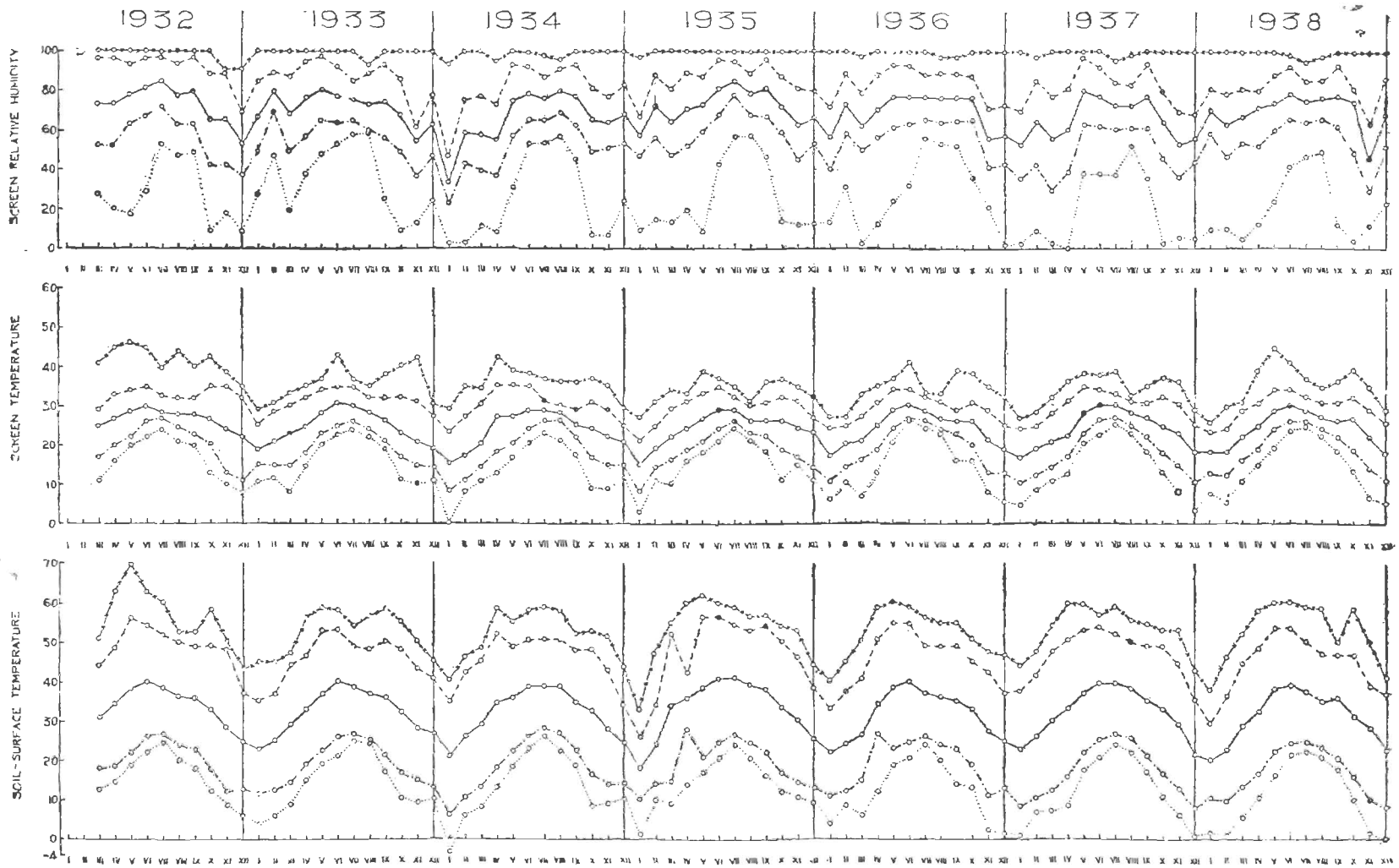
A study of the life-history of the locust has shown that, on an average, a female locust can lay about 200 eggs, and supposing that all the eggs hatch and grow into adults without succumbing to attack by enemies, there would be two hundred locusts at the end of the breeding. Should these newly fledged locusts be able to reach maturity without much delay, there would be, supposing that the progeny is composed of an equal proportion of males and females, about one hundred females ready to lay eggs, in the second generation. In case conditions favour a rapid succession of broods, there would be a hundred-fold increase in numbers with each successive generation. However, environmental resistance is met with at every stage. Some of the eggs may not hatch on account of defective soil moisture. Many of the hoppers may succumb to the attack of natural enemies mainly birds, as also a good proportion of the adults. If conditions are favourable locally for oviposition and breeding, there may not be any serious decrease in numbers before a new brood is brought into existence, but if the new adults have to migrate long distances for breeding, there is a definite risk of depletion of numbers so that the initial population available for starting a new brood will be definitely smaller. Our experimental studies have shown that the acceleration of sex-maturation of fresh adults is largely dependent on the availability of fresh plant food and to a less extent on the prevalence of optimum conditions of temperature and humidity. In the event of the presence of the requisite degree of soil moisture as the result of

Text Figure 6]



GRAPH SHOWING THE VARIATIONS IN THE MONTHLY AVERAGE DAILY MEAN OF SCREEN TEMPERATURE FOR THE YEARS 1932-1938 AT PASNI

Text Figure 7]



GRAPH SHOWING FLUCTUATION OF SCREEN HUMIDITY, SCREEN AND SOIL SURFACE TEMPERATURES DURING 1932-38 AT PASNL

HIGHEST MAXIMUM — MEAN DAILY MAXIMUM — DAILY MEAN — MEAN DAILY MINIMUM — LOWEST MINIMUM

adequate rainfall, egg may be laid at once; otherwise oviposition may be delayed considerably. It is thus seen that environmental resistance is fairly strong at every stage in the life-history of the locust, and it is only when conditions are very favourable for a rapid growth of hoppers and for an acceleration of the sex-maturation of the adults, as well as for the starting of a new brood without loss of time, and various factors of environmental resistance are thus eliminated, that the population of the locust can be rapidly built up. As in the course of crowded breeding, hoppers are compulsorily thrown very much into each other's company, they are likely to develop crowd psychology and evolve into *gregaria* swarms.

In the course of ecological studies, endeavours were made to secure a correlation between the behaviour of the locust and the conditions of its environment. Some interesting results were obtained with reference to (1) its breeding, (2) its daily activity, (3) its migration and (4) its overwintering, and a few notes are given below on the observations recorded.

I. Breeding. In nature, breeding is dependent on the existence of optimum conditions of atmospheric temperature and humidity, the presence of lush vegetation and of the requisite amount of soil moisture. In winter and early spring, temperatures are too low to allow of breeding, and it is only when the daily mean rises above 20°C. that locusts manifest signs of reproductive activity in north-west India. At other parts of the year when the temperature conditions are satisfactory, the main factors are the requisite degree of soil moisture and the availability of plant-food. In nature, however, these conditions are fulfilled only when there is requisite rainfall, in the absence of which, conditions of desiccation and drought prevent the occurrence of breeding.

Conditions under which breeding occurred at Pasni, Ambagh and Chachro have been studied during a series of years, and the results have been plotted in bioclimatographs,—one for each year, wherein the situation as regards temperature, rainfall and breeding month by month has been graphically shown. In cases where there was no effective rainfall during the year as at Pasni during 1934 and 1937 and at Ambagh in 1935, there was no breeding at all. In other years, breeding occurred within two or four weeks of a fall of rain of about two inches or above, if the temperature was high enough. At Pasni, a second brood occurred in April-May, 1933, following a heavy fall in the first week of April, and similarly, a second brood occurred in 1936 and 1937 at Chachro with an effective fall of rain in September. Usually there is little summer rainfall at Pasni, but when a heavy fall of about 6 in. occurred in July, 1932, it was followed by heavy breeding (*vide* Bioclimatographs for Pasni, Ambagh and Chachro) (Text Figs. 10-12).

II. Daily rhythm of locust activity. Some observations on the daily rhythm of the locust were made by Dr. Karandikar at Pasni in 1932, and under his instructions regular notes on the rhythmic activity of locusts in cages were taken in 1933 at Pasni by Mr. A. C. Sen. Further observations were made in December 1934 and January-May 1935 by Karandikar and Sen on locusts confined in large field-cages. In October 1935, Mr Taqi Ahsan carried out observations on the movements of green hoppers in the field. No further work was undertaken after this, as the Locust Committee that met in January 1936 considered that this line of work might best be taken up at a subsequent period when the gregarious form should again be available for experimentation.

Such observations as had been recorded during the years 1932—1935 were studied by Dr. M. L. Roonwal and notes prepared by him on the general results were included in the Annual Report for 1935. Extracts from these notes are given below, after careful revision. It should,

however, be kept in mind that they are the results of only preliminary work, which might have formed the basis for more detailed observations, if it had been continued.

Notes on the daily rhythm of the Desert Locust at Pasni, Mekran Coast, 1932—35

As the main factor governing the daily activities of locusts is apparent-by the temperature prevailing at particular parts of the day, the observations recorded have been arranged according to the season of the year. For the sake of convenience, the year has been divided into three types of seasons.

A. *Hot season.* April to October. Average screen temperature 26° to 32°C.

B. *Mild* or *transition season.* February—II half; March; November; Average screen temperature 19° to 24°C.

C. *Cold season.* December, January and I half of February. Average screen temperature 15° to 21°C.

For the sake fo convenience, the day has been divided from the point of view of the daily rhythm, into (1) *Morning* 6—9 A.M.; (2) *Forenoon* 9—11. A.M.; (3) *Afternoon* (including midnoon) 11 A.M. to 5 P.M.; (4) Evening 5 to 8 P.M., and (5) *Night* 8 P.M. to 6 A.M. (In these notes, A.T. signifies air temperature in the open, and S.T. Temperature of soil surface.) Most of these observations were made on non-gregarious adult locusts kept in large field cages, and on cage-bred black hoppers kept in field cages of different sizes.

N.B: At Pasni the time kept is Indian Standard Time, which is 5 hours and 30 minutes in advance of Greenwich Mean Time. Pasni local time is 1 hour and 20 minutes behind Indian Standard Time. The daily activities of locusts are governed by time based on sun-rise and sun-set, and it might have been a better plan, therefore, to study their daily rhythm in terms of local time, so as to make these observations comparable with those made in other localities.

A. HOT SEASON

1. *Adults.*

N. B. These observations were made in August, 1933 in a cage 3 ft. by 3 ft. and in May 1935 in a large field-cage.

Morning: 6 A.M. Activity beginning; A.T. 24°C.

7. A.M. Activity beginning; A.T. 24°C.

8 A.M. Active and feeding; jumping on approach; A.T. 26°C.

9 A.M. Active and feeding; jumping on approach; A.T. 26°C.

Afternoon: 12 NOON 1, 2, 3, 4, 5 P.M. Active and feeding, flying on approach A.T. about 32°C.

Evening: 6 to 9 P.M. Fairly active when approached.

Night: No observations on record.

2. *Black Hoppers* (I Stage)

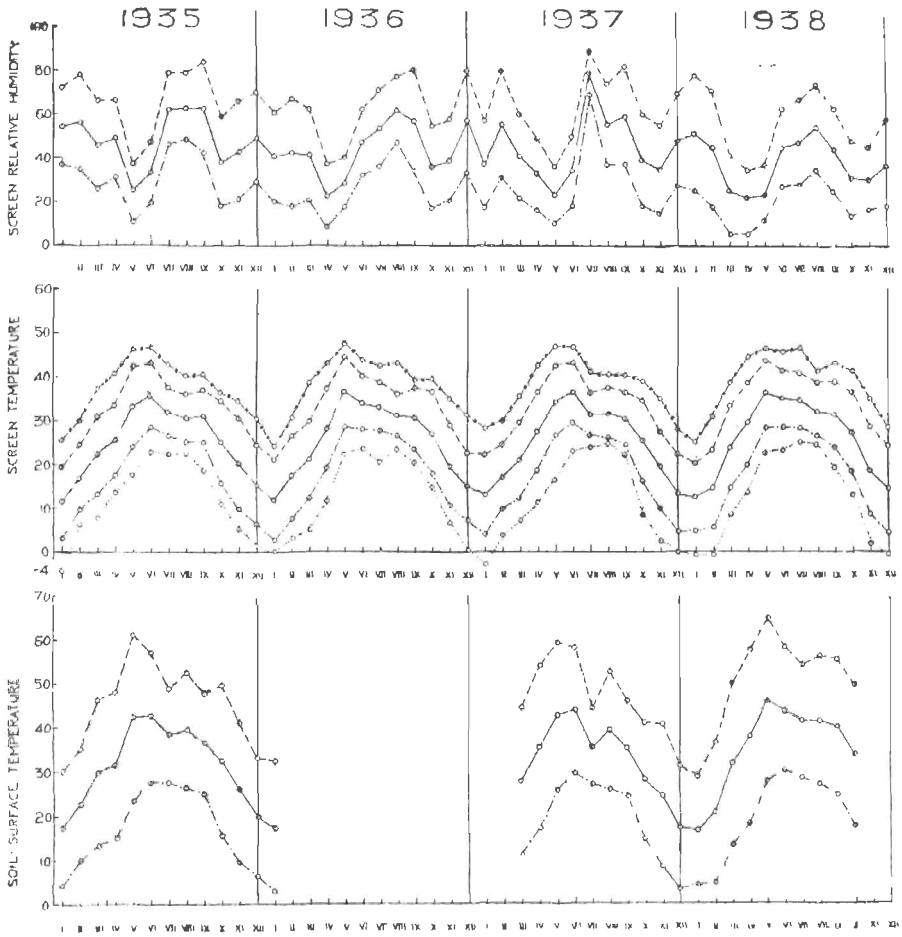
N.B. Observations made in August 1933, in cage 3 ft. by 3 ft. by 3 ft.

Morning: 6 A.M. A.T. 24°C; inactive.

7 A.M. (after sun-rise): A.T. 24.5°C.

Hoppers slowly crawl out of bush and station themselves on side of cage, facing the early morning sun. Beginning to be active.

Text Figure 8]



GRAPH SHOWING FLUCTUATION OF SCREEN HUMIDITY, SCREEN AND SOIL-SURFACE TEMPERATURES DURING 1935-1938 AT SARDARSHAHR

HIGHEST MAXIMUM — MEAN DAILY MAXIMUM — DAILY MEAN — MEAN DAILY MINIMUM — LOWEST MINIMUM

Text Figure 9]

QUADRAT VII

CHART QUADRAT (30 FT BY 30 FT.) OF DESERT VEGETATION (IN UNCULTIVATED FIELD) CHACHRO, SIND ON 21ST SEPTEMBER 1935.

AKH = AKHROO (*Melothria*) ; B = BOOH (*Aerua*) ; C = AK (*Calotropis procera*) ; M = MURANT (*P. luxgidum*)
P = PHOG (*Calligonum*) ; V = VISHANI (*Tephrosia*) ; W = WEKRA (*T. Cordifolia*) ⁘ GRASS ANNUALS (*Bharut, Gandhil*)

8 a.m. A.T. 26°C: Sitting on top of bush or on sides of cage basking in the sun.

9-10 a.m. A.T. 28·5°C; S.T. 30°C: Forming aggregations on top of bush or on cage floor and basking in the sun.

Mid-day: A.T. 34·5°C; S.T. 38°C: Aggregations dissolve at mid-day on account of excessive heat.

Afternoon: A.T. 34°C; S.T. 37°C: Aggregations of hoppers are re-formed on the floor of the cage.

6 P.M. A.T. 28°C; S.T. 31·5°C: Aggregations become dispersed hoppers climb the cage-sides to face the setting sun.

7 P.M. A.T. 25°C; S.T. 26°C: Hoppers begin entering bush

Night: A.T. below 24·5°C; Hoppers on bush in a condition of repose.

Hoppers are recorded as having come out of the bush, occasionally at an air temperature lower than 24·5°C; and to have climbed the cage-side to face the rising sun. In such cases, it was obviously the light rather than the temperature that provoked these movements. Since the rays of the sun contain both radiant heat and radiant light, the hoppers are presumably attracted out of the bush by the early morning rays as there is nothing to dissociate radiant heat from light.

3. *Green hoppers (I—IV stages)*

N.B.—Observations in large field cage in April-May 1935.

Morning: 7 A.M. A.T. 18°C: Inactive, sitting inside bush.

Forenoon: 10 A.M. A.T. 26°C: Crawling about on bush and sometimes hopping.

Afternoon: 2 P.M. A.T. 34°C: Very active, jumping on approach; feeding.

Evening: 7 P.M. A.T. 28·4°C: Mostly inside bushes, but quite active.

B. COLD SEASON

Adults

N.B.—Observations were made in December 1934 and January 1935 in large field-cages.

Morning: (Sunrise about 8 A.M.). 8 A.M. A.T. 19°C: Movements beginning; but rather sluggish.

9 A.M. A.T. 24°C: Beginning to be active, basking in the sun.

Forenoon: 10 A.M. A.T. 24°C: Fairly active; basking.

11 A.M. Active and flying about.

Afternoon: 12 NOON to 5 P.M.: A.T. 25°C rapidly rising after mid-day; S.T. 27°C.

Actively flying: pairing observed.

Evening: 6 P.M. A.T. 24°C; S.T. 21°C: Getting sluggish.

7 P.M. A.T. 22°C; S.T. 19°C: Found hiding in corners of cage: inactive.

8 P.M. A.T. 21°C: Inactive.

C. MILD (OR TRANSITION) SEASON

1. *Adults*

N.B. Observations were made in February and March 1935 in large field cages.

Morning: (Sun-rise about 7·30 A.M.) 8 A.M. A.T. 19·5°C; S.T. 19°C: Inactive.

9 A.M. A.T. 21°C; S.T. 21·5°C: Many inside bush showing slight movements; some basking.

Forenoon: 10 A.M. Showing signs of activity.

11 A.M.: Active.

Noon and afternoon: 12 NOON to 4 P.M.: Active; feeding; pairing; ovipositing.

5 P.M. A.T. 23·5°C; S.T. 24·5°C: Showing indications of retirement into bushes; one female was ovipositing.

Evening: 6 P.M.: Sluggish.

7 P.M.: Very sluggish.

8-9 P.M.: Inactive.

Night: 10 P.M. A.T. 19°C; S.T. 18 C: Mostly inactive; but one female was boring into soil for oviposition.

2. *Green hoppers (I to IV stages)*:

N.B.—Observations made in September 1935 in the rek areas.

Morning: 7 A.M.: Inactive.

8 A.M.: Found on bush-tops basking.

9 A.M. A.T. 21°C: Seated on bush-tops basking in the sun; some feeding.

Forenoon: 10 A.M. A.T. 32°C; S.T. 38·5 C: Some sitting quiet: others feeding.

11 A.M. A.T. 32°C: Some on bush-tops basking; others moving about or feeding.

Mid-day and Afternoon: 12 NOON to 5 P.M.: Similar activities as above.

Evening: 6 P.M.: Moving towards bush-tops; a few feeding.

7 P.M. A.T. 24·8°C; S.T. 26·5°C: Some on bush tops; others moving inside bush.

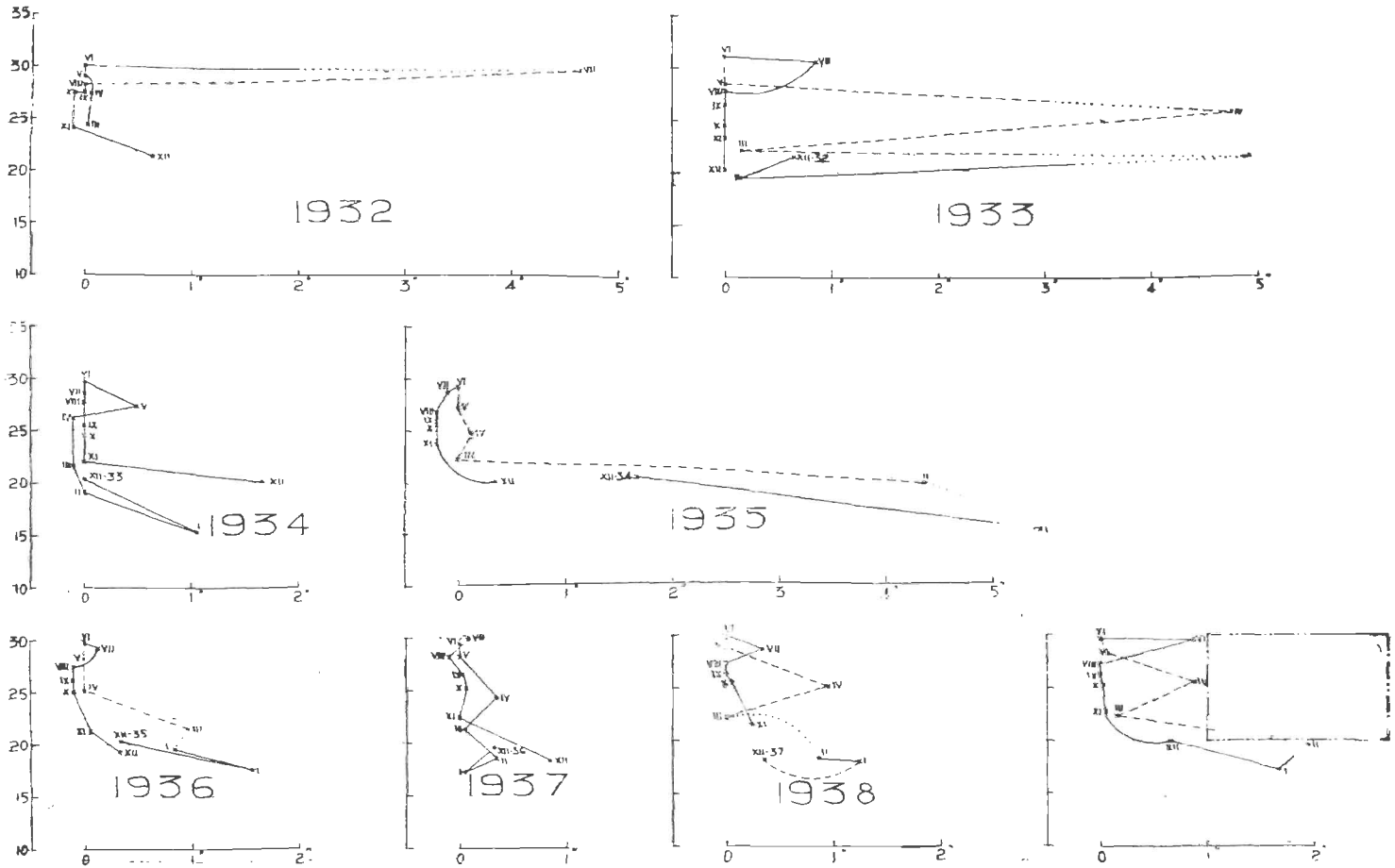
OBSERVATIONS ON MOVEMENTS OF GREEN HOPPERS IN FIELD

During the last week of September, 1935 Mr Taqi Ahsan introduced 23 individuals of first stage green hoppers on a bush in the morning. When examined in the evening, only three hoppers could be seen on that bush. On making a search for the missing hoppers, he found many of them on bushes 30 yards away. These hoppers were noticed to be present on these bushes when examined the next morning, but were found to have moved off by 10 o'clock. These observations suggest that green hoppers are capable of making considerable movements in the field as individuals. Such movements would appear to be specially common when a fair number of hoppers, five to ten or more, happen to be present on a bush, as obviously they are to a certain extent affected by each other's movements.

These are supported by Kennedy's elaborate experiments and observations made on the wandering capacity of grown-up hoppers under natural conditions at Hamashiameb on the Red Sea Coast [Kennedy 1939]. His

Text Figure 10]

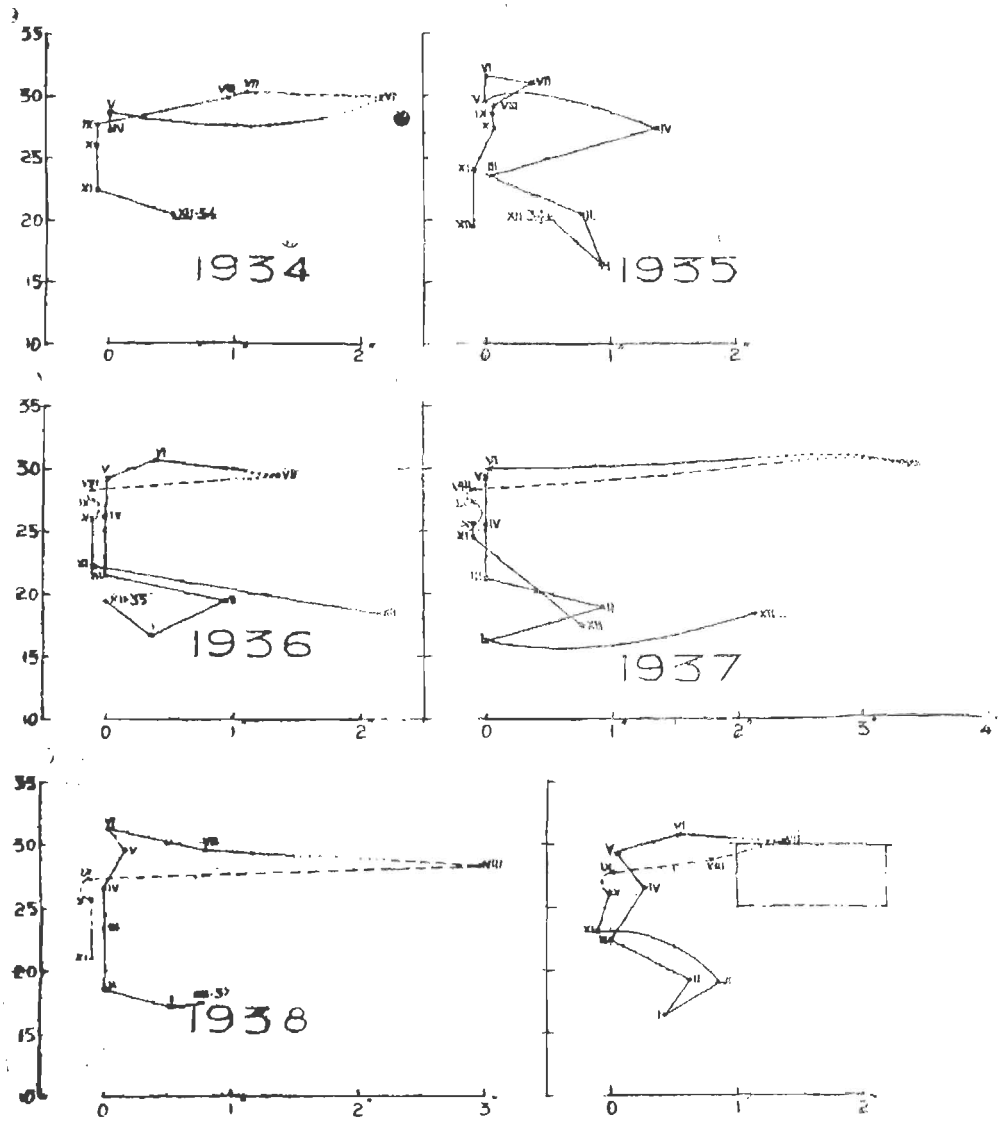
BIOCLIMATOGRAPHS FOR PASNI, SHOWING THE RELATIONSHIP OF LOCUST BREEDING WITH RAINFALL & TEMPERATURE DATA FOR THE YEARS 1932-38



(ORDINATES: IN DEGREES CENTIGRADE; ABSCISSAE: RAINFALL IN INCHES)

Text Figure 11]

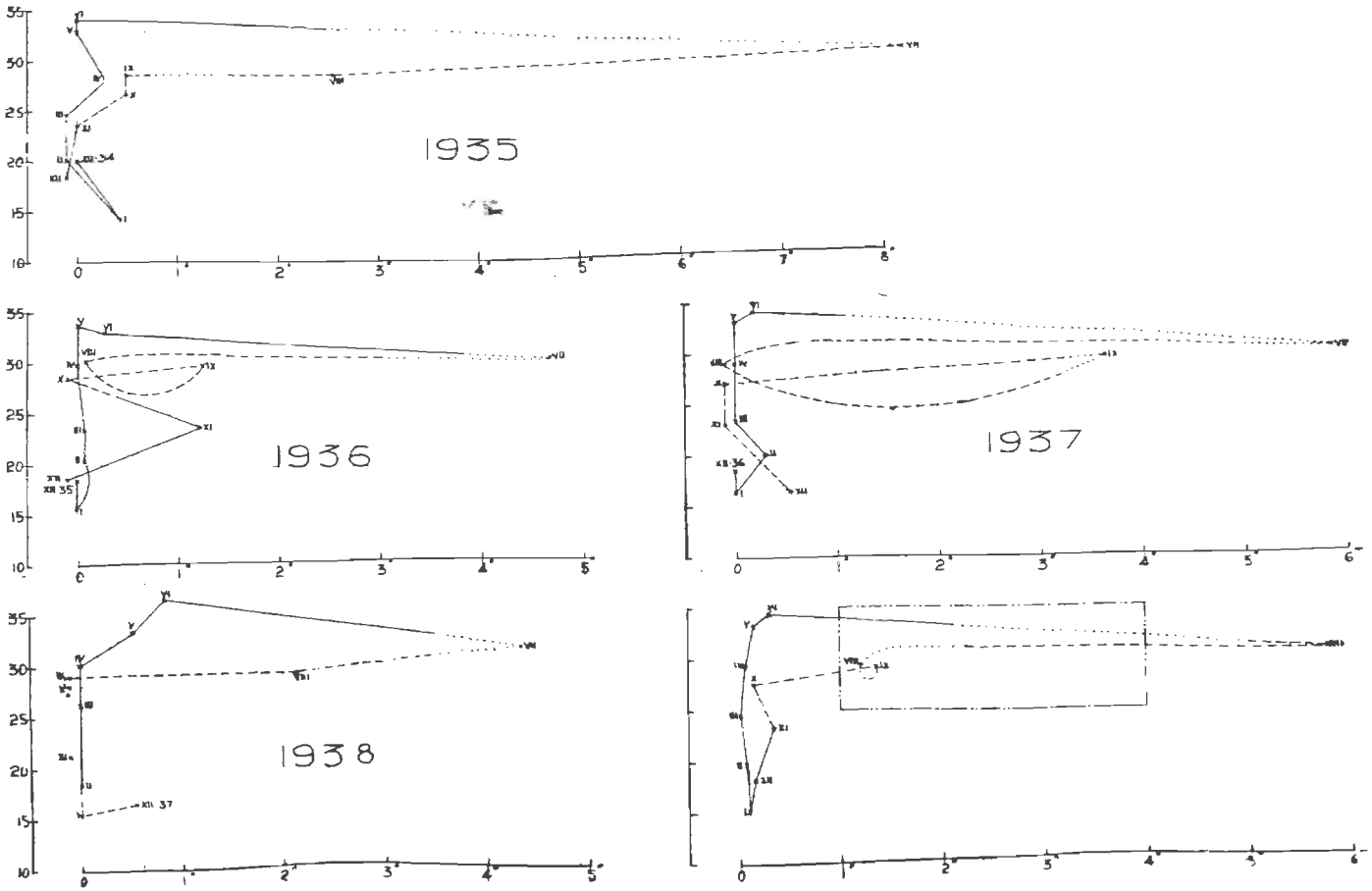
BIOCLIMATOGRAPHS FOR AMBAGH, LASBELA STATE, SHOWING THE RELATIONSHIP OF LOCUST BREEDING WITH RAINFALL & TEMPERATURE DATA FOR THE YEARS 1934-38.



(ORDINATES: IN DEGREES CENTIGRADE; ABSCISSAE: RAINFALL IN INCHES)

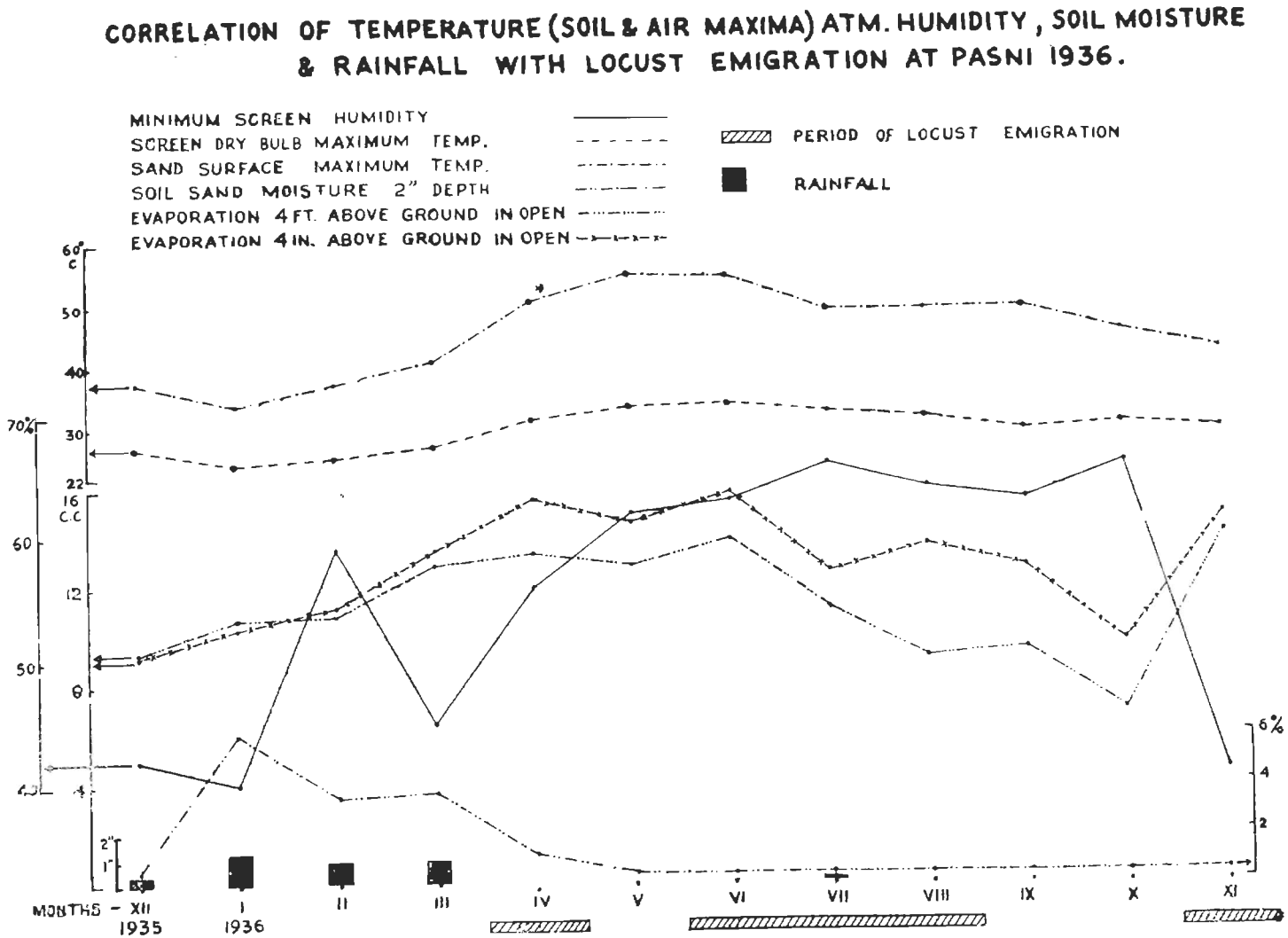
Text Figure 12]

BIOCLIMATOGRAPHS FOR CHACHRO, SHOWING THE RELATIONSHIP OF LOCUST BREEDING WITH RAINFALL & TEMPERATURE DATA FOR THE YEARS 1935-38.



(ORDINATES: IN DEGREES CENTIGRADE; ABSCISSAE: RAINFALL IN INCHES)

Text Figure 13]



studies of the behaviour of hoppers and adults in relation to the fluctuation of diurnal temperatures and his able analysis of the factors concerned throw, moreover, very valuable light on the problem of the daily rhythm of the locust.

III. MIGRATION OF ADULT LOCUSTS. In the course of survey work, it has often been noticed that though there may be a definite rise in the numbers of locusts at the end of a period of heavy breeding, a fall in the density of population is always noticed after a time. Similarly, in years of mass-multiplication too, the general experience is that at the end of spring breeding in the interior of Baluchistan, the new generation of locusts is present in large numbers during April and May, but that by June most of them are found to have disappeared. In these cases it is evident that the decrease of population is the result of the occurrence of a migration out of these areas. In the course of a study of the result of the locust surveys conducted during the years 1931 to 1938, it was found as already set forth in the chapters under Section III, that, year after year, a disappearance of locust population had been occurring in the winter rain areas at the end of spring breeding and similarly in the summer-rain areas in autumn at the end of summer breeding. An examination of the meteorological data at these periods showed that the shifting of populations was presumably due to the development of conditions of high saturation deficiency as a result of a rise of temperatures and a fall of atmospheric humidity. In connection with a study of the data leading to the heavy incursion of locusts into Pasni in July 1935, it was found (*Vide* Chap. IV, of Sec. III) that it was obviously due to the rise of temperatures and the development of hot north-west winds in the interior of Mekran during the week preceding. It was subsequently noticed that even at Pasni, in spite of the high atmospheric humidity due to maritime influence, the population was decreasing in July and August, presumably by emigration. As a similar shifting of population was noticed at about the same time during 1936 and 1937, a study of the various meteorological elements concerned was made during the years 1935 to 1938, with a view to find out the main factor causing the migration. A study was similarly made at Chachro of the changes that take place in the climatic conditions of the desert at the time of the withdrawal of the monsoon, so as to find out how they affect locust movements. A short account has already been given of the developments observed in Chapter V, of Sect. III, and it is proposed here to study the influence of the different elements with the aid of graphs.

I. *Study of factors causing migration at Pasni*

Solitary type locusts are generally found on the surface of sandy soils and only such elements as affect the soil surface have been taken for study.

Among the ecological factors affecting the soil-surface, the following data only were obtainable at the Pasni station: surface temperature, evaporation at a height of 4 in, soil-moisture, and rainfall. No data were available regarding atmospheric humidity at the soil surface, but this is not a serious defect in view of the availability of figures for evaporation at a height of four inches. The following factors have been included in the graph:

1. *Temperature.*—Soil-surface mean maximum, and screen daily maximum (monthly average).
2. *Humidity.*—Screen relative humidity minimum (monthly average).
3. *Evaporation* (Piche's Evaporimeter).—Monthly average at (a) 4 inch height in open air, and (b) 4 feet height in open air.

4. Monthly rainfall in inches.

5. Soil-moisture percentage at 4 inch depth (monthly average).

These factors have been correlated with periods in which locust emigration is known to have occurred.

From the graph (Text Fig. 13) it is seen that surface temperature and screen temperature vary directly with each other, rising in summer and falling in winter. It is also seen that relative humidity of the atmosphere (screen) and evaporation vary *inversely*. The curve of screen humidity rises in winter and spring with rainfall, but its further rise in summer is entirely due to the influence of the sea. The curves of evaporation at 4 in. height and 4 ft. height show interesting differences; whereas in the colder months, especially when there is winter rainfall, there is not much difference between them, there is higher evaporation at a height of 4 in. than at 4 ft. during the summer months. This would indicate that air humidity at soil-surface is much lower than at a higher level. As there is little soil-moisture at 2-inch depth from April onwards, as may be seen from the graph, there appears to be little doubt that the layers of the atmosphere at the soil-surface partake, during daytime, more of the degree of humidity derived from the upper layers of the soil, than what may be derived from the moist currents from the sea. The periods of locust emigration noted at Pasni would appear to synchronize with periods of high evaporation at 4 in. height and with those in which the soil moisture is low.

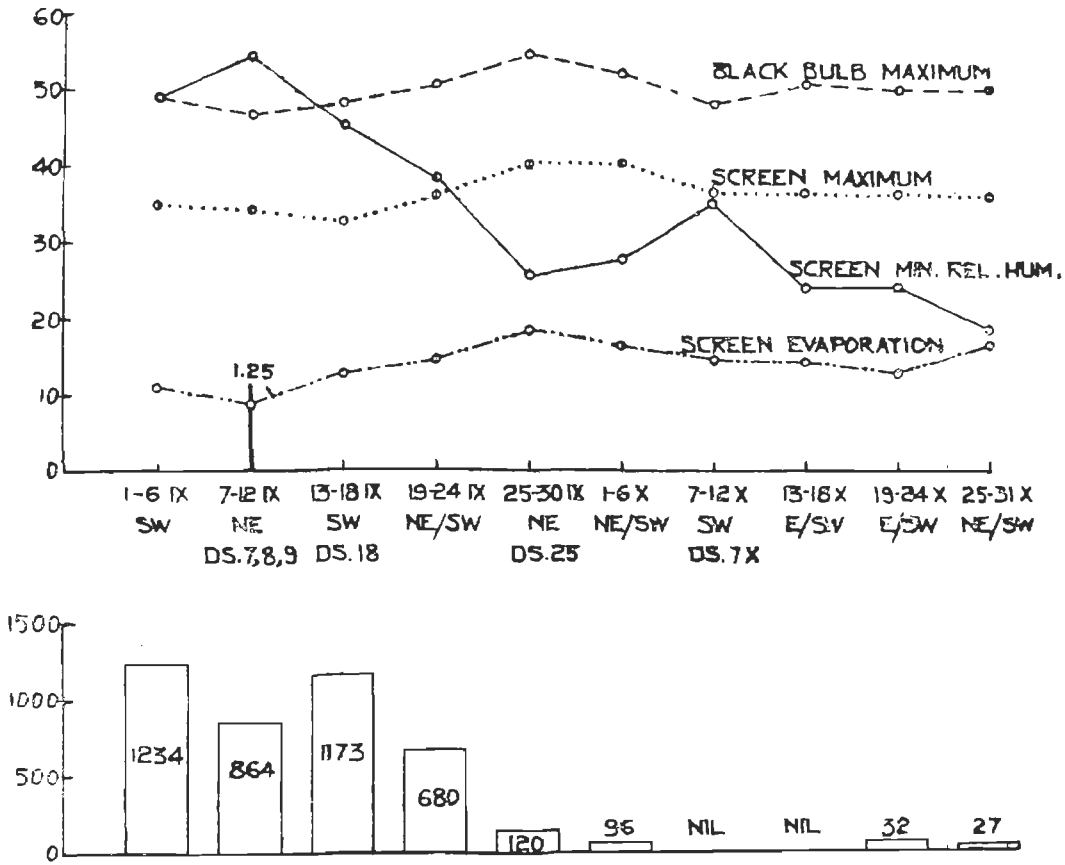
As already mentioned in the account of locust surveys in 1935 (Chap. IV), spontaneous flights of solitary locusts were noted just after sunset on 17, 18, 19, and 25 July 1935 at Pasni. The screen temperature of the atmosphere at that time varied between 27°C and 28°C and the atmospheric relative humidity was about 80 per cent., but at the soil surface the temperatures may be presumed to have been higher by about 2 degrees, and the humidity of air at soil surface was probably low as there was very little soil-moisture at that time. It is probable that as, with the normal inversion of temperatures after sun-set, the soil-surface gets cooler, and as, with gusts of the strong sea-breeze, the higher humidity of the upper layers of the air penetrates up to the soil surface, the changes in the temperature and humidity of the soil-surface thus brought about may provide locusts with the stimulus for seeking a change of place. They have been found to behave in a more or less similar manner at the approach of dust or rain storms (*vide* Year 1937).

2. *Study of factors causing emigration at Chachro*

In studying the conditions obtaining during the period of transition between the closing stages of the monsoon and the setting in of winter, the following factors were taken into consideration: Black bulb maximum at soil surface, screen maximum temperature, screen minimum humidity, evaporation in screen, wind-direction and the occurrence of dust or rain storms. These have been correlated with results of survey data on the density of population.

The data available for a period of two months from 1 September to 31 October, 1936 were plotted in a graph for purposes of study. The period was divided into ten sub-periods of six days each, and averages of the figures for the different factors were calculated for entering them in the graph (Text Fig. 14). From an examination of the graph, it is seen that the Black Bulb and the Screen maxima show parallel variation, while the curves of minimum relative humidity and evaporation show

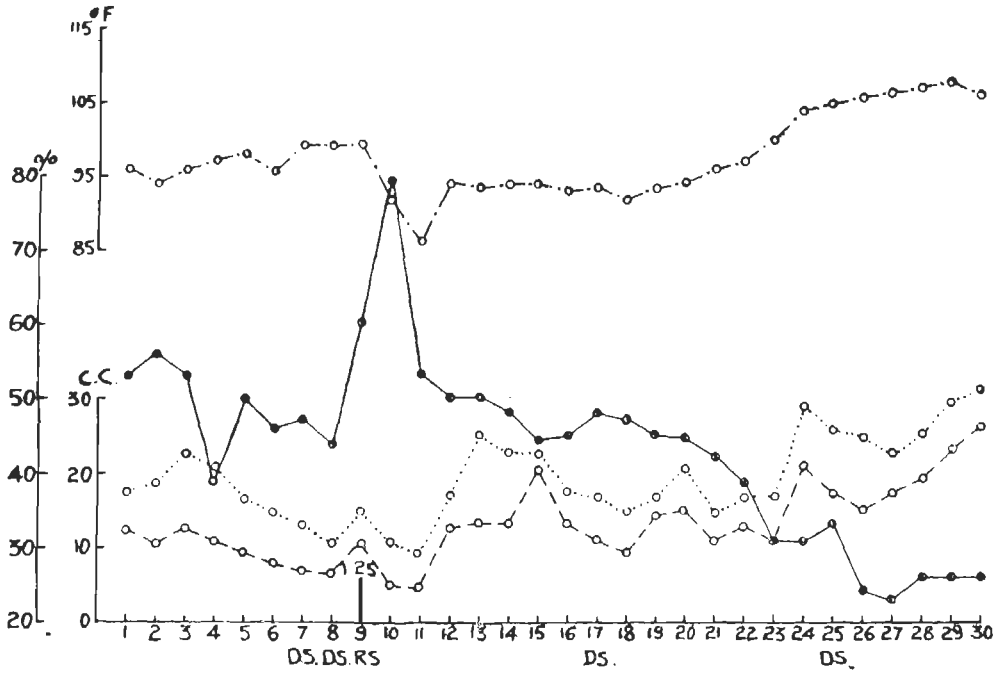
Text Figure 14]

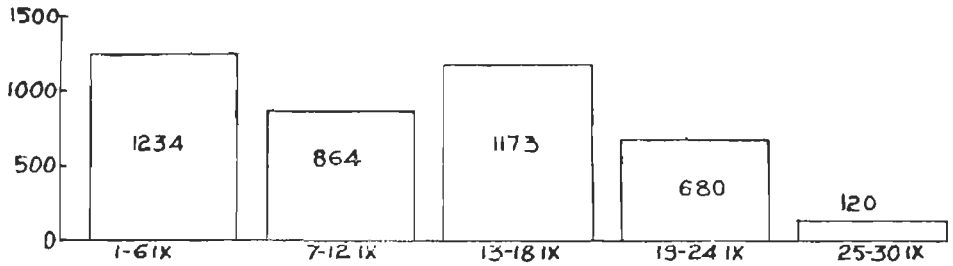


CORRELATION OF TEMPERATURE, HUMIDITY & EVAPORATION DATA WITH THE DISAPPEARANCE OF LOCUSTS AT CHACHRO, SEPT.-OCT. 1936.

RAINFALL IN INCHES. LOCUST POPULATION DENSITY PER SQ. MILE. E. NE. SW = DOMINANT WIND DIRECTION. DS. = DUST STORM

Text Figure 15]





GRAPH SHOWING THE CORRELATION OF DAILY CHANGES OF TEMPERATURE, HUMIDITY & EVAPORATION WITH FLUCTUATION OF LOCUST POPULATION AT CHACHRO IN SEPTEMBER 1936

SCREEN MAX: TEMPERATURE. — SCREEN MINIMUM HUMIDITY

EVAPORATION SUN. — EVAPORATION SCREEN

RAINFALL IN INCHES. — DS. = DUST STORM. RS. = RAIN STORM. — LOCUST POPULATION DENSITY PER SQ. MILE

inverse variation. With the exception of a short period, 7 to 10 September, when owing to the occurrence of dust-storms, and a fall of rain amounting to 1·25 inches on the evening of the 9th, there was a rise of humidity and a slight lowering of temperature, there would appear to have been a gradual rise of temperature and fall of humidity till the end of September. In October there was a fall of temperature and a rise of humidity till the middle of the month synchronous with the prevalence of south-west winds. In the latter half of October, there was a rise in evaporation and a fall of humidity, attended by the development of easterly and north-easterly winds.

A decrease in the locust population would appear to be associated (1) with the development of high temperatures and relatively high saturation deficiency of the atmosphere, and generally also, (2) with the occurrence of dust or rain storms. Following the occurrence of such storms on 7, 8 and 9 September there was a fall in the population, as also after the occurrence of a dust storm on the 17th. After the storm of the 25th afternoon, there was an almost total exodus of locusts from the neighbourhood of Chachro. As these storms are recorded as having occurred in the evening, between 4-30 and 8 P.M., it would appear as if the emigration had taken place in the evening or in the early part of the night, as at Pasni in July 1935.

Text Fig. 15 is designed to depict the changes that occurred day by day during September at Chachro, the elements included being: maximum screen temperature, minimum screen relative humidity, evaporation in the screen and in the open and the occurrence of dust-storms. The graph shows the fluctuation of the various elements concerned, day by day and especially the occurrence of a rise in the evaporative power of the atmosphere just prior to the occurrence of dust-storms. The fall in temperature, and in evaporation and a steep rise of humidity after the sharp shower of the 9th evening is also noteworthy. As the dust-storms usually follow periods of high temperature and low humidity and are, in fact, the result of a rush of cooler and moister air from outside, it would appear that locusts are stimulated into activity by the inversion of temperature and moisture that takes place at that time. The decrease of population that was noticed after the dust-storms of 7-9 September and the 17th and the 26th is quite significant.

IV. THE PHENOMENON OF OVER-WINTERING. In many parts of Upper Baluchistan, especially at altitudes higher than 4,000 ft. above sea-level, frosts occur almost every night during the greater part of December, January and February. There are records to indicate that swarms suffer a high percentage of mortality in the upland areas during winter. During locust survey work, cases of mortality among the solitary phase locusts during severe spells of cold weather were noticed. In winter, locusts seek the base of thick bushes like those of *siniya* (*Crotalaria burhia*), for protection from cold during nights, but they generally crawl out during day time to bask in the sun. In the Mekran coastal areas and in the desert generally, winters are not severe, but sometimes, especially in the northern parts of the desert as in the Bikaner area, frosts occur on several nights during cold waves, and at such times, locusts have been found dead at the base of the bushes. The following observations made of the behaviour of locusts in a cage (*vide* Pl. 32)—3 ft. by 3 ft. by 3 ft. with wire gauze sides kept in the open during the winter months at Quetta, however, indicate that locusts can withstand fairly low temperatures. In a cage set up in the compound of the office at Quetta, in which several hoppers had been introduced among small bushes to note changes

in coloration in September, a few became adults in October, but owing to the setting in of cold weather rather early by the middle of October and the occurrence of frost on several nights, the rest of the hoppers did not show any further growth during the winter. They were found hiding either at the base of thick bushes or in crevices between the framework of the cage and the ground during nights, and to come out of their hiding places at about 9 or 10 in the morning on sunny days. During the whole day they were noticed to remain basking in the sun, and to feed a little at midday on cabbage leaves provided inside the cage. They did not emerge, however, on cloudy days. The following were the temperature conditions at Quetta during the period of October 1931 to January 1932.

Monthly data for the period October 1931 to January 1932 at Quetta.

Month	Temperature (Degrees) F.					Humidity 8 a.m.	Rain fall	Amount of Cloud
	8 a.m.	Maximum		Minimum				
		Mean	Highest	Mean	Lowest	per cent.		
October, 1931	46·8	77·0	90·0	41·2	25·0	42	*Nil*	*Nil*
November, 1931	36·3	67·1	73·0	32·6	26·0	55	0·04	2·8
December, 1931	29·0	55·9	67·0	26·6	17·0	?	0·29	3·6
January, 1932	34·2	58·0	75·0 (31-i)	29·8	13·0 (13-i)	56	0·41 Snow on 9-i-32	5·3

The minima data refer to figures recorded in the screen, but the temperature on the soil surface was found to be lower by four to six degrees. The locusts, both hoppers and adults, were found to have survived till the beginning of January, so that they had apparently withstood air temperatures of 17°F. (about −8°C), but with the fall of snow in the second week of January and the subsequent thaw, they were observed to succumb to the wet cold.

In the course of survey work, observations were made on the overwintering habits of a few grasshoppers. At Quetta, *Acrotylus humbertianus* was found overwintering under grass in a lawn at a depth of about 1½ in. to 2 in. and to have survived a snow-fall of 4 in. in March 1931. *Anacridium aegyptium* was found hiding in a niche in a building at Quetta, in February 1931. At Ahmedwal in Chagai (3,000 ft. altitude), several specimens of *Thisoecetrus charpentieri persa* Uv. were collected on March 1st 1931, hiding in crevices in stony ground and to have survived a fall of snow. At Chachro in the cultivated area of the desert, several thorn fences—used for protecting fields from cattle trespass—were dismantled in February 1935 to find out if any individuals of the desert locust were hiding in them during the cold weather, and though the results were negative so far as the desert locust was concerned, several grasshoppers—*Cyrtacanthacris tatarica, Anacridium egyptium, Euprepocnemis alacris,* etc.—were found hiding in such situations (*vide* Section III, Chap. IV). On the Ambagh reks, various small grasshoppers were found hiding among clumps of *Panicum turgidum* and other grasses, in January 1935. At Nokh, a few grasshoppers were found dead at the

STATEMENT Ec. I

Some of the common Flora of the Pasni Rek area

S. No.	Natural Order and Scientific Name	Local Name	Annual or Perennial.
	AMARANTACEAE.—		
1	*Aerua tomentosa* Forsk. (*javanica* Juss)	*Balishtko* . . . *Balibur, Balishtbur*	P
2	*Amarantus blitum* L.	*Kalpir*	A
3	*Amarantus viridis* L.	*Maliro*	A
	APOCYNACEAE.—		
4	*Nerium odorum* Soland	*Jaur* (Oleander)	P
	ASCLEPIADACEAE.—		
5	*Calotropis procera* R. Br.	*Karagh*	P
6	*Glossonema varians* Bth	*Shagoshak*	A
7	*Leptadenia spartium* Wight	*Hub*	P
8	*Periploca aphylla* Decne	*Gishtar*	P
9	*Pentatropis spiralis* Decne	*Zamor*	P
	BORAGINACEAE.—		
10	*Arnebia hispidissima* DC	*Puzzo-Marrand*	A
11	*Gastrocotyle hispida* Bunge	*Bahar-Marrand*	A
12	*Heliotropium scabrum* Stocks		A
13	*Heliotropium strigosum* Willd.	*Geet-Kash*	A
14	*Heliotropium undulatum* Vohl	*Marrand*	P
15	*Sericostoma pauciflorum* Stocks (?) (*Kotchyi* ?)	*Madagi Kah* . *Kharzan*	P
	CAPPARIDACEAE.—		
16	*Capparis decidua* Pax. (*aphylla* Roth)	*Kaled*	P
17	*Capparis spinosa* La.	*Karap*	P
18	*Cleome brachycarpa* Vahl	*Meskuk*	P
	CARYOPHYLLACEAE.—		
19	*Sagina procumbens* L	*Kalagi-roum*	A
20	*Sphaerocoma aucheri* Boiss	*Mazoung*	P
	CHENOPODIACEAE.—		
21	*Anabasis* sp.	*Porant*	P
22	*Atriplex crassifolia* C. A. Mey	*Sorichk*	P
23	*Cornulaca monacantha* Del.	*Jhawad*	P
24	*Suaeda fruticosa* Forsk	*Reghit*	P
25	*Salsola* sp.	*Mesk*	P
26	*Salsola foetida* Del	*Sorag ; Hashaq*	P
	COMPOSITAE.—		
27	*Echinops tibeticus* Hg. T	*Zard-phul*	A
28	*Filago germanica* L.		A
29	*Ifloga fontanesii* Cass.		A
30	*Launea chondrilloides* DC	*Shartrak*	A
31	*Launea nudicaulis* Loess	*Haliko*	A
32	*Picridium tingitanum* Desf.	*Zaharichk*	A
33	*Pulicaria crispa* Bth.	*Sadap*	A
34	*Sonchus oleraceus* Linn	*Gokzaban*	A

S. No.	Natural Order and Scientific Name	Local Name	Annual or Perennial.
	CONVOLVULACEAE.—		
35	*Convolvulus microphyllus* Siob		A
36	*Convolvulus pleuricaulis* Choisy	*Daraj-bagal*	P
37	*Convolvulus beluchistanensis* Biswas	*Sheerwal*	P
38	*Coressa cretica* L.	*Leyyo*	A
	CYPERACEAE.—		
39	*Cyperus arenarius* Retz	*Kullichr*	P
	FICOIDEAE.—		
40	*Aizoon canariense* L	*Koochik-pad*	A
41	*Gisekia pharnacioides* L	*Lechaku, Maliro*	A
42	*Trianthema pentandra* L	*Guwal, Uyal, Kalper, Indar-Kah.*	A
	GRAMINEAE.—		
43	*Aeluropus villosus* Trin.	*Harchad*	P
44	*Agrostis stolonifera* Trin.	*Keertik*	A
45	*Andropogon annulatus* Forsk.	*Abdar-kah*	P
46	*Avena subspicata* Chiv.	*Sebra*	A
47	*Cynodon dactylon* Pers.	*Gandhil Kah.*	P
48	*Eleusine aristata*, Ehrenb. (*Dactyloctenium scindicum*, Boiss).	*Gondil*	P
49	*Eragrostis cilianensis*, Link, (= *major* Host)	*Maling, Zanzilokah*	A
50	*Eragrostis tremula* Hochst		A
51	*Halopyrum mucronatum* Staph	*Marundi*	A
52	*Heleochloa dura* Boiss	*Limmer, Mund*	P
53	*Panicum antidotale* Rets.	*Gomas*	P
54	*Panicum turgidum* Forsk	*Barshonk*	P
55	*Pennisotum cenchroides* Rich (= *Cenchrus ciliaris* L)	*Sibar*	A
56	*Pennisetum dichotomum*, Del.	*Barshonk*	P
57	*Poa persica Trin.* (Var)	*Arzan kah*	A
58	*Pogonotherum saccharoideum* Benth	*Koon-soomb*	A
59	*Schismus marginatus* Beauv	*Kunsoomb*	A
60	*Setaria viridis* Beauv	*Lechhuk*	A
61	*Sporobolus indicus* Br.	*Mond-kah*	A
62	*Tragus biflorus* (Roxb.) Schultz		A
	ILLECEBRACEAE.—		
63	*Paronychis argentea* Lam.		A
64	*Scleranthus annuus* L.		A
	LEGUMINOSAE.—		
65	*Acacia farnesiana* Willd.	*Chish*	P
66	*Acacia jacquemontii* Bth.	*Chagirdh*	P
67	*Alhagi camelorum* Fisch.	*Shinz*	P
68	*Astragalus tribuloides* Del.	*Kahur Bahar*	A
69	*Astragalus afghanus* Boiss	*Mathkinuk*	A
70	*Caragana cuneata* Baker.	*Maluri*	A
71	*Crotalaria albida* Heyne	*Tombo*	P
72	*Indigofera paucifolia* Del.	*Shimmir, Shimmid*	P
73	*Indigofera semitrijuga* Forsk	*Shonik-kush.*	H

S. No.	Natural Order and Scientific Name	Local Name	Annual or Perennial
74	*Lotus stocksii* Boiss	*Shanikkush*	P
75	*Parkinsonia aculeata* Lin.	*Babur* (Garden plant)	P
76	*Prosopis spicigera* L.	*Kahoor*	P
77	*Taverniera nummularia* DC.	*Lantu*	P
78	*Tephrosia hookeriana* W. & A.	*Mathkinuk*	P
79	*Trigonella corniculata* L.	*Shimsh*	A
	LILIACEAE.—		
80	*Asparagus curillus* Ham.	*Shalwardir*	P
81	*Asphodelus tenuifolius* Cav.	*Pimaluk*	A
	MALVACEAE		
82	*Malva parviflora* Linn.	*Gurag-pad*	P
	OROBANCHACEAE—		
83	*Orobanche* sp.	*Harisund*	A
	PALMEAE.		
84	*Phoenix dactylifera* Linn.	*Mach* (Cultivated).	P
	PLANTAGINACEAE.—		
85	*Plantago ovata* Forsk	*Danichk*	A
	POLYGONACEAE.—		
86	*Emex spinosa* (L) Camle.	*Hari-gosk*	A
87	*Pleropyrum ericoides* Boiss	*Karwankush*	P
	RESEDACEAE.—		
88	*Reseda aucheri* Boiss	*Mazaro, Mazardum*	A
89	*Zizyphus jujuba* Lamk.	*Kunar*	P
	ROSACEAE.—		
90	*Neurada procumbens* Linn.	*Naluko*	A
91	*Prunus eburnea* Aitch and Hemsley	*Jugar*	P
	RUTACEAE.—		
92	*Oldenlandia retrorsa* Boiss.	*Harab, Lilko*	P
	SCROPHULARIACEAE.—		
93	*Schweinfurthia sphaerocarpa* A. Braun.	*Durhund*	A
	SOLANACEAE.—		
94	*Lycium europaeum* L	*Joduk, Zarruk, Rinzuk*	P
	TAMARICACEAE.—		
95	*Tamarix dioica* Roxb.	*Gaz* (Pasni)	P
	ZYGOPHYLLACEAE.—		
96	*Fagonia cretica* L.	*Karkawag*	P
97	*Peganum harmala* L.	*Gandako, Spand*	P
98	*Tribulus terrestris* Linn.	*Kahur Bahar, Sareng*	A
99	*Zygophyllum coccineum* Linn.	*Shurdoo*	A
100	*Zygophyllum simplex* Linn.	*Sorru, Simour*	A

STATEMENT EC. II.

Some of the Fauna of the Pasni Reks

MAMMALIA

Hyaena hyaena Br.—The Striped Hyaena
Vulpes cana Blanf.—The Common Fox
Gazella bennetti (Sykes)—The Indian Gazelle.—
Cheliones hurrianoe (Jerd.)—The Desert Gerbill

AVES (Birds)

Fam. *Corvidae :*

Corvus corax ruficollis (Less). (*Corvus umbrinus* Hed.) Brown-necked Raven, ' Kalag' (Baloch)

Fam. *Turdidae :*

Monticola solitaria pandoo (Sykes):. Indian Blue Rock-Thrush : 'Brinji-sesu'.
Oenanthe deserti atrogularis (Blyth.): Gould's Desert Chat. 'Hari-siaholan'——Winter Migrant.
Oenanthe capistrata (Gould) : White-headed Chat. : 'Hari-siaholan'——Winter Migrant.

Fam. *Laniidae :*

Lanius excubitor lahtora (Sykes.) : Indian Grey Shrike : 'Gehanch'.

Fam. *Sturnidae :*

Sturnus vulgaris humii (Brooks) : Himalayan Starling : ' Tiliar' Migrant.
Pastor roseus (Linn.) : Rosy Pastor; Jowari Bird: Starling; ' Tiliar' ; Migrant.

Fam. *Fringillidae :*

Emberiza melanocephala Scop.: Black-headed Bunting : 'Chittock' 'Nambi', 'Zarrichk' ' Droochk', —Winter Migrant.
Passer domesticus indicus (Jerd. & Sel.) : House Sparrow :

Fam. *Motacillidae :*

Anthus sordidus jerdoni (Finsch) : Brown Rock Pipit ; ' Pinkluk' : Migrant.
Anthus richardi rufulus (Vieill. . Indian Pipit : ' Tissu ' :
Motacilla flava beema (Sykes) : Indian Blue-headed Wagtail : 'Pinji' : Migrant.

Fam. *Hirundinidae :*

Hirundo rustica rustica (Linn.) : Common Swallow : ' Ababil' —Migrant.

Fam. *Alaudidae :*

Galerida cristata chendoola (Franklin) : Crested Lark : 'Chagonk.'
Alaemon alaudipes doriae (Salvad.) : Persian Desert Lark : 'Shepanko'; 'Zanikrep.'
Alaudula raytal adamsi (Hume): Indus Sand-Lark : ' Toppi'.
Eremopteryx (Pyrrhulauda) grisea grisea (Scop.) : Ashy-Crowned Finch-Lark : ' Dugga

Fam. *Coraciidae :*

Coracias benghalensis benghalensis Linn. Indian Roller : ' Kangashk'.
Coracias garrula semenowi Loud & Tchusi : Kashmir Roller : 'Kangashk'—Migrant.

Fam. *Meropidae* :

Merops orientalis biludschicus Neumann : The Sind Green Bee-Eater : "Darkoon".

Fam. *Upupidae* :

Upupa epops epops Linn. The European Hoopoe : ' Murgh-i-Suleiman' —Migrant.

Fam. *Captimulgidae* :

Caprimulgus europaeus unwini Hume : Unwin's Night-Jar : 'Bohant' —Winter : Migrant.

Fam. *Aegypiidae :*

Neophron percnopterus percnopterus (Linn.) White Scavenger Vulture : ' Gootoo'.

Fam. *Falconidae* :

Falco peregrinoides babylonicus Gurn. ' Shahin' Falcon.
Astur gentilis gentilis (Linn.) : The Goshawk 'Baz'. Migrant.

Fam. *Pteroclidae* :

Pterocles coronatus Licht. Coronetted Sand-grouse: 'Khattakar ,

Fam. *Burhinidae* (*Oedicnemidae*):

Burhinus oedicnemus astutus Hart. Persian Stone-Curlew : 'Charaz'.

Fam. *Glareolidae* :

Cursorius cursor cursor (Latham) : Cream-coloured Courser : 'Tangoo'.

Fam. *Scolopacidae* :

Tringa hypoleucas Linn. The Common Sand-Piper :—'Kog'.

(*N.B.*—Most of the birds listed were collected by Mr Taqi Ahsan in 1938.)

REPTILIA

LACERTILIA

Fam. *Lacertidae* :

Acanthodactylus cantoris cantoris Gunth.

Fam. *Gekkonidae* :

Hemidactylus turcicus (Linn.) (in houses)
Stenodactylus orientalis Blanf. (on sand).

Fam.. *Agamidae* :

Agama agilis Oliv.
Phrynocephalus ornatus Boul

Fam. *Scincidae* :

Eumeces schneideri (Daudin).
Ophiomorus brevipes Blanf. 'Reg Mahi'.

Fam. *Varanidae* :

Varanus griseus (Daud.)

OPHIDIA

Fam. *Viperidae* :

Echis carinata (Schneider) : Sand-Viper 'Garr'

Fam. *Colubridae* :

Zamenis ventrimaculatus (Grey) Rat-Snake
Zamenis diadema Schleg.
Dipsas (*Dipsadomorphus*) *trigonata* (Schnelder).
Tropidonatus subminiatus Schleg.
Psammophis leithii Gunther

BATRACHIA

ANURA

Rana hexadactyla Less.
Rana cyanophlictis Schn.

Bufo viridis Laur.

ARTHROPODA

I. CHILOPODA

Fam. *Scolopendridae* :

Scolopendra morsitans Linn.

2. ARACHNIDA

Fam. *Scorpionidae* :

Butheolus melanurus K.
Buthus macmahoni Poc.

Fam. *Ixodidae*

Hyalomma sp.

Fam. *Trombidiidae* :

Trombidium grandissimum L.

Fam. *Tyroglyphidae* :

Tyroglyphid Mite on Schistocerca. (unidentified).

Fam. *Galeodidae*

Galeodellus sp.
Galeodes sp.

Fam. *Argyopidae* :

Heremia sp.

3. INSECTA

ORTHOPTERA

Fam. *Acrididae* :

Acridella procera (Klug.)
Mioscirtus wagneri rogenhoferi Sauss.
Acrotylus humbertianus Sauss.
Sphingonotus mecheriae Kr.
Sphingonotus savignyi Sauss.
Tmethis hotsoni Uv.
Derycoris ramachandrai Uv.
Chrotogonus robertsi Kir.
Atractomorpha sp.
Anacridium aegyptium (L.)
Calopteropsis glaucopsis Wlk.
Thisoecetrus charpentieri Uv.

Aeolopus affinis I. Bol.
Locusta migratoria L. ph *solitario*
Oedaleus senegalensis Kr.
Sphingonotus rubescens Wlk.
Sphingonotus nebulosus discolor Uv.
Derycoris xenosterna Uv.
Scintherista notabilis brunneri Sauss.
Pyrgomorpha sp.
Tenuitarsus sp.
Schistocerca gregaria (Forsk.) ph. *solitaria*.
Thisoecetrus littoralis asiaticus Uv.
Calliptamus siculus deserticola Voss.

Fam. *Tettigoniidae* :

chizodactylus monstruosus Drn.

Phaneroptera albida Wlk.

Fam. *Gryllidas* :

Gryllus domesticus L.

Liogryllus bimaculatus De. G.

Fam. *Mantidas* :

Blepharopsis mendica F.
Eremiaphila braueri Kr.

Empusa uvarovi Chop.

ISOPTERA

(Termites)

Fam. *Calotermitidae* :

Hodotermes macrocephalus Holmgren. (Found cutting grass blades).

Fam. *Termitidae* :

Microtermes sp. (attacking wood.)

ODONATA

Fam. *Libellulidae* :

Tramea basilaris burmeisteri Kirby
Pantala flavescens Fb.
Orthetrum sabina Drury
Crocothemis servilia servilia Drury
Crocoothemisserviliaerythraea Drury.

Fam. *Aeschnidae* :

Hemianax ephippiger Burm.

HEMIPITERA

Fam. *Cydnidae*
Cydnus indicus Wstw

Fam. *Lygaeidas* :

Lygaeus creticus Luc.
Coenocoris nerii Germ. (On Oleandar)
Graptostethus sp.

Fam. *Cicadidae* :
Cicadatra anoea Wlk.

Fam. *Coccidae*:

Lecanium (*Saissetia*) *oleae* Colvie (On *Cordia*)
Parlatoria oleae Colvi. (On *Cordia* sp.)
Margarodes (*Neomargarodes*) *niger* I Green.
On roots of grass clumps in sandy soil (*Halopyrum mucronatum*)

NEUROPTERA

PLANIPENNIA

Fam. *Myrmeleonidae* :
Myrmecaelurus trigrammus Pall.
Palpares solidus Grst.
Acanthaclisis sp.

Fam. *Nemopteridae*
Halter mutans Nav.

LEPIDOPTERA

Fam. *Pyralidae* :
Antigastra catalaunalis Dup.
Hymenia fascialis Cram.
Nomophila noctuella Schiff.

Fam. *Nymphalidae* :
Danais chrysippus L.
Precis orythyia swinhoei Butl.

Fam. *Lycaenidae* :
Lampides boeticus L.
Zizeeria lysimon Hb.

Fam. *Sphingidae* :
Acherontia styx Westw.
Celerio lineata F.
Cephonodes picus Cram.
Herse convolvuli L.

Fam. *Noctuidae* :
Achaea catella Guen.
Phytometra ni Hb.

Fam. *Pterophoridoe*
Agdistis adactyla Hb.

Fam. *Pieridae* :
Colotis danae F.
Colotis eucharis F.
Teracolus danae F.
Pieris glaucomoma Klug.
Belenois mesentina Cram.

Fam. *Hesperiidae* :
Spialia foris evanidus Butl.

Fam. *Geometridae* :
Tephrina subocellata Was.

Fam. *Arctiidae* :
Utetheisa pulchella L.

COLEOPTERA

Fam. *Carabidae* :
Chlaenius sp.
Carabus sp.

Fam. *Dytiscidae* :
Cybister tripunctatus Ol.

Fam. *Buprestidae* :
Cyphosoma lawsoniae Chev.
Julodis variolaris Pall.
Aaata ffinchi Waterh.

Fam. *Tenebrionidae* :
Pimelia indica Sen.
Himatismus villosus Haag.
Spyratheus sp.

Fam. *Anthicidae*:
Anthicus tobias Mars.

Fam. *Prionidae* :
Acanthophorus nigriceps Gal.

Fam. *Curculionidae* :
Ammocleonus aschabadensis Fst.

Fam. *Melydridae* :
Cylindrothorax angusticollis Kolv. var. *suturella* Haag.

Fam. *Bostrychidae* :
Bostrychus sp.

Fam. *Elateridae* :
Agrypnus heridus F.

Fam. *Meloidae* :
Lytta myrmida Fairm.
Mylabris angulata Kl.
Mylabris goryi Mars.
Mylabris schach Redt.

Fam. *Heteroceridae* :
Heterocerus turanicus Ltt.

Fam. *Scarabaeidae* :
Sub-fam. *Dynastinae* :
Pentodon bispinifrons Rtt.

Sub-fam. *Coprinae* :
Scarabaeus sacer L.
Heliocopris gigas L.
Gymnopleurus atratus Klug.

Sub-fam. *Geotrupinae*
Athyraeus orientalis Lap.

Sub-fam. *Aphodinae* :
Aphodius lividus Ol.

HYMENOPTERA

Fam. *Ichneumonidae* :
Cremastus sp.

Fam. *Braconidae* :
Glyptomorpha nursei Cam.
Glyptomorpha smenus Cam.
Cardio chilus sp. near *fulvus* Cam.
Iphiaulax sp.

Fam. *Chrysididae* :
Stilbum cyanurum F.

Fam. *Vespidae* :
Vespa orientalis F.
Polistes hebraeus F.

Fam. *Sphecidae* : (*Sphegidae*)
Sceliphron bengalense Dahlb.
Sceliphron pictum Sm.
Ammophila smithii Baly.
Ammophila erythrocephala F.
Chlorion regalis Sm.
Cerceris nursei Turn.
Bembex mediterranea Handl.
Bembex dahlbomi Handl.

Fam. *Formicidae* :
Cataglyphis pallida Mayr.
Cataglyphis viatica L.
Monomorium salamonis indicum Fer.
Tanaemyrmex sp.

Fam. *Mutillidae* :
Apterogyna savignyi Kl.

Fam. *Eumenidae* :
Eumenes dimidiatipennis Sauss.

Fa. *Pompilidae* (*Psammocharidae*)
Batozonus unifasciatus Sm.
Cryptochilus flavus F.

Fam. *Apidae* :
Megachile flavipes Spin.
Colletes nursei Cam.
Anthophora mucorea Kl.

Fam. *Xylocopidae* :
Xylocopa fenestrata F.
Xylocopa violacea L.
Xylocopa leucothorax (De Geer)

DIPTERA

Fam. *Tabanidae* :
Tabanus rubidus Wied.
Tabanus orientis Wied.

Fam. *Bombyliidae* :
Thyridanthrax sp.
Plesiocera flavifrons Back.

Fam. *Muscidae* :
Musca domestica L.

Fam *Anthomyidae* :
Atherigona indica Malloch
(Maggots in juar shoots)

Fam. *Asilidae* :
Stenopogon sp.
Philodicus sp.

Fam. *Calliphoridae* :
Rhynchomyia calopis Lw.
Sarcophaga hirtipes Wied.
Rhynchomyiopsis indica Towns.
Chrysomyia albiceps Wied.
Wohlfahrtia nuba Wied.

Fam. *Hippoboscidae* :
Hippobosca capensis v. Olf.
Hippobosca camelina Leach.

APHANIPTERA
(Fleas)

Fam. *Pulicidae* :
Pulex irritans L.

base of bushes in addition to some specimens of the desert locust in February 1937 after a frost. These observations show that overwintering is a fairly common phenomenon among many of the Acrididae found in Indian area.

CHAPTER III

BIOMETRICAL STUDIES OF THE DESERT LOCUST

IT is now fairly well-recognized that the extreme forms of the *greparia* phase—as met with in swarms at the height of the outbreak—are strikingly different from tpyical *solitaria* individuals observed in swarmless intervals in the desert areas. There are marked differences between them in (1) coloration, (2) the proportions of the different parts of the body, and (3) behaviour. Whereas locusts found in swarms are generally devoid of distinct stripes on the body and in the eyes, but are strikingly coloured (the immature locusts being pink in colour and the mature ones bright yellow) the non-gregarious adult individuals have distinct stripes on the body as well as in the eyes, and a grey brown coloration which blends with its surroundings. In the younger stages the solitaria hoppers are green in colour and are inconspicuous on the green bushes on which they live, while the *gregaria* hoppers are prominently coloured in black and yellow, and are usually found crowded together in bands, capable of actively marching long distances. There are considerable differences in the structure of the body between the two phases. Compared with the solitary form, the gregarious individual has longer wings, shorter hindlegs, a somewhat swollen face and a pinched thorax. In behaviour, the *solitaria* form loves to segregate itself from its fellows and is, on the whole, inactive, whereas the *gregaria* individuals live a crowded and very active life both in the hopper and adult stages.

However, all gradations between these two extremes are to be found in nature. Even at the peak of the development of the *solitaria* forms in the monsoon breeding of 1936, fair numbers of the intermediate forms as well as a few *gregaria* individuals were noticed. On the other hand, at the time of the locust incursion of 1935 on the various reks of Mekran, there was a high proportion of *transiens* and *gregaria* ratio, while the *solitaria* forms were relatively few. It was also observed that the great majority of the immigrants, irrespective of whether they were *gregaria or transiens* and in a few cases even *solitaria* in their ratios, were pinkish in colour when they first appeared, and did not possess bodystripes. After about four to six weeks, however, all the forms found on the different reks, such as Pasni and Ambagh, were found to have developed distinct stripes and the typical grey-brown *solitaria* coloration, though their biometrical ratios were of the 'incursion' types with a preponderance of *transiens* and *gregaria* forms. It has been shown in an earlier chapter that the adult locust is capable of adapting its general coloration to a certain extent to that of its environment, and it is, therefore, evident that coloration cannot be taken as a sole criterion in determining the affinities or phase of individual locusts.

Lespes, Regnier and Rungs [1930] found that in Morocco the earlier flights of the year 1927 consisted almost entirely of *solitaria* and intermediate types, and that it was only later on as the infestation intensified that swarms of the typical *gregaria* type were observed as in 1929 and 1930. At the time of the incursion of 1935, the *gregaria* forms formed only 25 to 30 per cent. of the population, the rest being made up of *transiens* and *solitaria,* so that the population noticed at this time was evidently of the same character as that observed in Morocco in 1927 by Lespes, Regnier and Rungs. It is probable that if the incursion forms of 1935 had multiplied, the population might have developed into pure *gregaria* in the course of two or more generations.

Change of colour among hoppers from green to black by crowding and from black to green by isolation is well-known, and as green hoppers usually develop into *solitaria* adults, and black ones into *gregaria*, a change of phase occurs by crowding or isolation among hoppers. Husain and Mathur [1936] have brought valuable experimental evidence to show that hoppers may assume a black coloration by reason of excessive physical activity, in spite of being reared in isolation. In some cases, stray specimens of *gregaria* adults have been met with in nature in the midst of a *solitaria* population, which had acquired their *gregaria* characters possibly because the hoppers had to undergo active individual wandering in nature as a result of scarcity of food or high temperatures. Volkonsky [1938] has adduced interesting evidence in regard to a change of phase among adults by crowding, leading to a change of colour and to the production of a progeny of black hoppers. He has suggested that the origination of the outbreak centres in the interior of Mekran in 1935 might have been due to a change of phase psychology in the adult stage as a result of a concentration as adults and a subsequent crowded egg-laying, giving rise to *gregaria* hoppers from the very start.

These observations indicate that, prior to morphological or biometrical changes, changes in behaviour may occur, and lead to physiological and psychological changes in the insect. A higher metabolic activity and a crowd mentality are presumably developed before actual morphological changes are noticed. Kennedy [1939] confirms the above conclusions when he says: 'biometrical changes lag behind colour and behaviour changes in the phase cycle, in view of the circumstance that groups of individuals of apparently biometrically *solitaria* forms may behave like a *gregaria* swarm, and *vice versa*, apparently solitary locusts may be biometrically gregarious.'

Experience indicates that in the evolution of outbreak centres what really matters is the development of environmental conditions favourable to the formation of concentrations of adults, no matter what their phase may be and to the occurrence of crowded breeding, leading to an accumulation of hoppers within confined areas. In the generation that emerges from such crowded breeding, it is very likely that a large proportion of individuals with higher ratios (*transiens* and *gregaria*) will be found, and in case these meet with conditions favouring further concentrated breeding, pure *gregaria* swarms may be formed. If, on the other hand, they come across environmental conditions, such as dense growths of vegetation as is often met with in the Rajputana desert areas as the result of high rainfall—the dense plant growth will, as suggested by Kennedy [1939], function as a brake on hopper movements and cause them to lose touch with one another and revert to the solitary mode of life. The progeny of a population with fairly high biometrical ratios may under such conditions turn out to be largely *solitaria* in character.

Morphological differences of phase in SCHISTOCERCA GREGARIA

The existence of phase difference among locusts was first shown by Uvarov [1921], who proved, on the basis of his studies of the European Migratory Locust,—*Locusta migratoria migratoria* (L)—in southern Russia, that what was formerly known as *Locusta danica* L. was merely the solitary phase form of the Migratory Locust. By the possession of a highly convex dorsal crest on the prothorax and of a bright green and brown coloration, the form *danica* presents such a vastly different appearance from that of the migratory form that Uvarov's hypothesis was violently opposed at the beginning. Experimental work by Faure [1928, 1932] and Zolotarevsky [1933], and field observations made by various workers, such as Johnston [1926], Maxwell-Darling [1936] and others have served not only to substantiate the existence of phases in various other species of locusts, but also to bring proof in regard to the transformation of the solitary phase into the migratory and *vice versa*.

The solitary phase form of the desert locust was originally described as a different species, *Schistocerca flaviventris* Burm. It can be readily distinguished (1) by its grey-brown coloration with stripes of brown and yellow, and (2) by the morphological peculiarities of its head and body, from the *gregaria* form, which is usually bright pink when immature and bright yellow when sexually mature. As already shown, the coloration of locusts is very variable. Whereas individuals composing flying swarms are often pink, it has been found that when they get segregated from swarms and become scattered in the deserts, they assume a type of coloration very much like that of solitary forms. In certain cases, it has been observed that individuals which are typical *solitaria* forms morphologically might acquire a bright yellow coloration. It has, therefore, been found rather difficult, in practice, to distinguish phases by coloration alone. On the other hand, morphological differences between the phases are apparently stable and the ratios of the length of certain parts of the body exhibiting phase variation have been utilized to classify forms from the point of view of phase development. As different workers, however, had adopted different ratios and also different methods of expressing the ratios, and it was obviously necessary to bring about uniformity in biometric work for facilitating a comparison of the results

STATEMENT B. R.—I.

Analysis of biometrical measurements in Schistocerca gregaria *showing the relationship of E/F to other ratios*

Solitaria	Ratios: 1·88 to 2·05								
Locality	Date	Year	Eye stripes	Sex	E/F	P/C	M/C	H/C	C O
Pasn . .	ix-x	1932	7	♂	1·88	1·538	0·830	1.200	..
Chachro . .	viii	1934	7	♀	1·92	1·617	0·888	1.185	1.08
Khandewari .	xi	1934	7	♂	1·93	1·471	0·757	1.214	1.04
Chachro . .	viii	1934	6	♂	1·94	1·454	0·848	1.166	1.02
Bhadka . .	28-ix	1934	7	♀	1·95	1·500	0·878	1.195	1.09
Rumra . .	26-ix	1937	6	♂	1·97	1·563	..	1.236	..
Groshak . .	17-ix	1932	6	♂	1·98	1·514	0·794	1.220	..
Chachro . .	30-v	1936	6	♂	1·98	1·430	..		1.03
Mandvi . .	6-v	1934	7	♂	1·99	1·486	..	..	1.05
Chachro . .	9-iv	1936	7	♀	2·00	1·466	..	..	1·03
Pasni . .	30-v	1935	?	♀	2·03	1.470	0·843	1.192	..
Chachro . .	16-viii	1934	?	♀	2·03	1·564	0·870	1.258	1·05
Pasni . .	20-i	1935	?	♀	2·03	1·435	0 858	1.223	..
Chachro . .	21-ix	1935	?	♀	2·03	1·564	0·884	1.256	..
Pasni . .	19-i	1935	?	♀	2·04	1·462	0·774	1.174	..
Rumra . .	30-iii	1938	6	♀	2·04	1·461	..	1.236	..
Range of variation					1·88 to 2·04	1·617 to 1·430	0.888 to 0·757	1.258 to 1·166	
Average ratios					1·98	1·499	0·839	1·212	

Transiens	Ratios 2·06 to 2·15								
Locality	Date	Year	Eye stripes	Sex	E/F	P/C	M/C	H/C	C/O
Pasni . .	10-ii	1932	6	♂	2·07	1·400	0·785	1·071	..
Chachro . .	viii	1934	7	♂	2·07	1·410	0·835	1·191	1·04
Tar Charnor .	12-viii	1934	6	♂	2·07	1·462	0·820	1·224	1·06
Chachro . .	viii	1934	6	♀	2·07	1·454	0·870	1·155	1·07
Chachro . .	viii	1934	6	♂	2·07	1·409	0·722	1·212	1·03
Ambagh . .	i-iii	1934	7	♂	2·08	1·425	0·887	1·212	1·03
Pasni . .	i-iii	1932	6	♀	2·10	1·437	0·812	1·187	..
Pasni . .	ix-x	1932	6	♀	2·15	1·315	0·875	1·137	..
Range of variation					2·07 to 2·15	1·462 to 1·315	0·887 to 0·722	1·224 to 1·071	.. ..
Average ratios					2·08	1·414	0·825	1·174	..

Gregaria	Ratios 2·16 to 2·34								
Pasni . .	26-iv	1931	6	♀	2·17	1·379	0·805	1·097	..
Ambagh . .	3-x	1935	1	♂	2·17	1·333	0·746	1·120	1·19
Pasni . .	24-i	1932	6	♂	2·18	1·253	0·733	1·040	..
Bhagori (Ambagh)	13-iv	1938	6	♀	2·19	1·359	..	1·099	..
Pasni . .	25-xi	1931	6	♂	2·20	1·243	0·714	..	..
Pasni . .	viii	1932	6	♂	2·20	1·325	0·775	..	1·17
Pasni . .	viii	1932	6	♂	2·22	..	..	1·115	1·19
Bhagori (Ambagh)	13-viii	1938	6	♀	2·24	1·362	..	1·125	..
Pasni . .	iii	1932	6	♂	2·25	1·321	0·705	1·007	..
Ormra area .	1-13-x	1935	7	♀	2·26	1·385	0·771	1·180	1·18
Pasni . .	23-v	1931	6	♀	2·26	1·387	..	1·187	..
Rumra . .	26-xi	1937	6	♀	2·28	1·306	..	1·167	..
Pasni . .	iii	1932	6	♂	2·32	1·312	0·775	1·100	..
Pasni . .	i-iii	1932	6	♂	2·32	1·308	0·756	1·051	1·20
Range of variation					2·17 to 2·32	1·387 to 1·243	0·805 to 0·705	1·187 to 1·040	.. ..
Average ratios					2·23	1·329	0·753	1·113	..

of different workers, it was unanimously resolved by the 3rd International Locust Conference to recommend workers to adopt the method of measurements employed by Zolotarevsky in his work on *Locusta migratoria capito* Sauss. [1933].

Zolotarevsky found that the elytron of the *gregaria* form was longer, the hind femur shorter, the pronotum contracted and depressed in the middle, and the face broader at the region of the cheeks as compared with the *solitaria,* (*vide* Text Fig. 16) and he adopted the following ratios for expressing the degree of phase development:—E/F or length of elytron/length of posterior femur; P/C or length of pronotum/maximum width of head; H/C or height of pronotum/maximum width of head and M/C or width of constriction/maximum width of head. Of these, however, workers have found after experience that the ratio between the lengths of elytron and the hind femur is not only the most expressive but also one that could be most accurately determined [Uichanco and Gines, 1937]. In general, the E/F ratio is taken for specifying the phase character of specimens and the other ratios are used only when the elytra and the femora are damaged or lost or for confirmation in cases of doubt.

Biometrical work carried out under the scheme

The first attempts at biometrical examination of locusts collected in the field were made in 1932, and some work was also done in 1934. It was not, however, till the writer took several boxes of collections with him to London at the time of the third International Locust Conference in 1934 and worked out the biometrics of a good part of the collection with the kind help of Dr. B. P. Uvarov at the British Museum, that real work was begun. After return to Karachi the writer continued his work during his leisure time, till a biometrical assistant (Rashid Ahmad) was appointed in August 1935. As, however, owing to the exigencies of field work in Mekran, he had to be posted at Pasni for a considerable period of time, he could in fact devote only about five months to biometrical work, before he was finally transferred to Pasni in May 1936. Biometrical work was begun in earnest in October 1936, when R. L. Gupta was appointed and by the time he left the scheme on 31 March, 1939, he had accomplished a very large amount of patient and accurate work dealing with the biometrical analysis of most of the collections of the period 1934 to 1938. In addition to *Schistocerca*, he also examined several boxes of *Locusta migratoria* collected when the latter was found in destructive numbers in N.W. India in 1937 [Gupta, 1939].

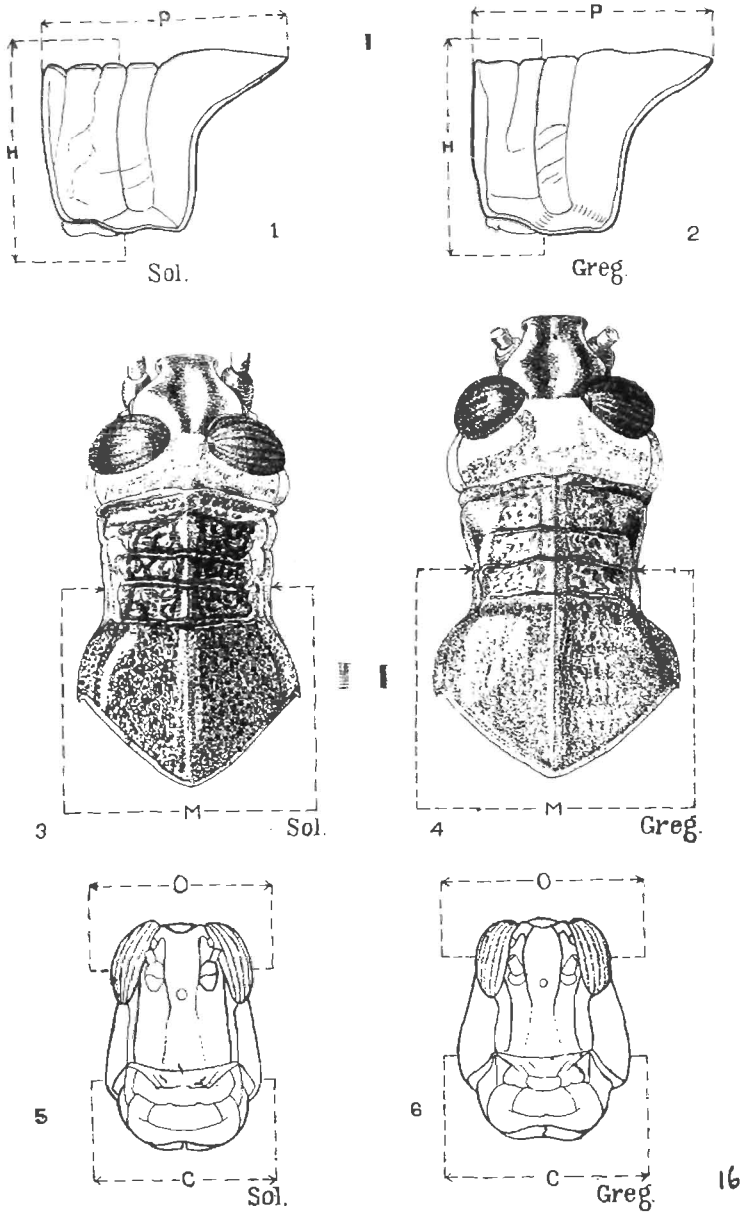
During his spare time, the writer continued his studies of certain ratios other than the recognized ones in respect of the measurement of damaged specimens and some of the results obtained will be set forth in the following paragraphs.

STATEMENT B.R.—II

Locality	Date of Collection	Eye-stripes	Anten. segm.	Phase	E	F	P	M	H	C	E/F	P/C	M/C	C/H
					Measurements in millimeters						Ratios			
				MALE SPECIMENS										
Nokh	8-vi-35	6	?	*Solitaria*	52·2	25·8	10·0	5·6	8·3	6·65	2·02	1·504	0·842	1·249
Quetta (swarm)	28-vi-31	6	26	*Gregaria*	52·2	23·7	9·5	5·1	8·0	7·2	2·20	1·319	0·708	1·111
Nokh	27-viii-36	7	29	*Solitaria*	53·7	26·2	9·8	5·7	8·1	6·6	2·05	1·484	0·863	1·226
Baluchistan	1931	6	26	*Gregaria*	53·7	24·1	10·0	..	8·0	7·3	2·23	1·369	..	1·096
Choyan-Lathi	22-viii-36	6	?	*Solitaria*	50·7	25·8	9·5	5·5	7·9	6·5	1·97	1·461	0·846	1·215
Loralai	3-viii-31	6	26	*Gregaria*	50·8	22·5	8·4	5·3	7·3	6·8	2·26	1·235	0·779	1·058
				FEMALE SPECIMENS										
Pugal	16-viii-36	6	27	*Solitaria*	57·8	28·4	10·4	6·3	8·3	7·1	2·03	1·464	0·887	1·169
Sharigh	31-vii-31	6	26	*Gregaria*	57·8	26·1	10·1	6·6	8·9	8·2	2·21	1·231	0·805	1·085
Adasti (Pasni)	21-v-36	7	28	*Solitaria*	58·1	28·5	11·0	6·7	8·9	7·2	2·04	1·528	0·930	1·236
Loralai	5-viii-31	6	26	*Gregaria*	58·1	26·5	10·5	6·5	8·9	7·9	2·19	1·328	0·822	1·126
Bagori (Ambagh)	6-i-37	6	27	*Solitaria*	61·1	29·8	11·0	6·6	9·0	7·3	2·05	1·566	0·904	1·232
Quetta	18-vi-31	6	26	*Gregaria*	61·1	26·8	10·6	6·5	9·0	8·1	2·28	1·808	0·802	1·301

N.B.—" E " stands for ' Length of elytron ';; " F " for ' Length of posterior femur; "P" for 'Length of pronotum' " M " for 'Widthat constriction of pronotum'; " H " for ' Height of pronotum '; and " C " for 'Maximum width of Head,.

Text Figure 16]



Structural differences between phases solitaria and gregaria : Figs. 1 & 2: Sideview of Protherax ; Figs. 3 & 4 ; Dorsal view of Head and Pronotum; & Figs. 5 & 6: Contour of face: 'P'-Length of pronotal crest; 'H'-Height of pornotum ; 'M'-Breadth of pronotum at constriction; 'C'-maximum width at genal area of face; 'O'-maximum width at ocular area of face.

Text Figure 17]

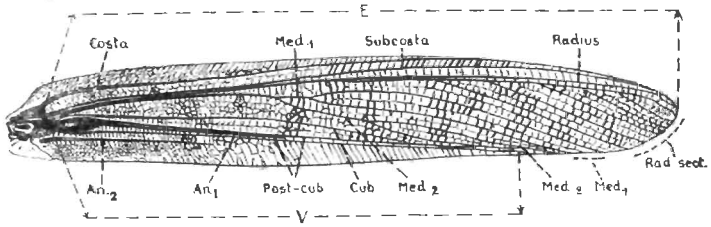


Fig 17 (a)

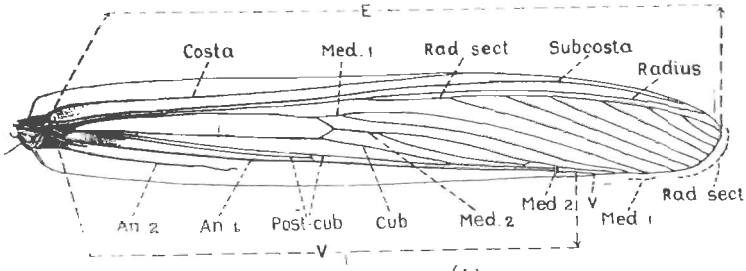


Fig. 17 (b)

Venation of Tegmen of the Desert Locust, Fig.(a) showing venation including nervures. Fig.(b) the as without nervures. The following veins are shown Costa, Sub-costa; Radial, Radial Sector with branches; Median, anterior and posterior with branches; Cubitus, Post-cubitus, Cubito-median cross-vein; Anals : 1 & 2; 'V'-the apex of the Anal (for Vannal area) of Tegmen.

In the course of a biometrical examination of specimens, all information pertaining to the specimen under examination was entered in a register, including the date and details of collection, the sex, the number of eye-stripes, the number of antennal segments, the color of the body and the hind-wings, and the presence of any ectoparasites and algae. Usually only the elytra and the femora were measured and the E/F ratios worked out, but in the case of damaged specimens, the thoracic ratios were determined to fix the phase of the specimen.

In the early part of the work, dividing callipers and a metal scale were used, but were not found satisfactory for taking accurate measurements. Later on sliding callipers with vernier scale were employed and in order to secure high accuracy, the measurements were taken under the magnification of a large-sized reading glass mounted on a stand. Among the callipers tested, a sliding type with a dial to show the measurements in tenths of a millimeter was found to be the best.

Correlation between the different biometrical ratios

As already mentioned, the ratio between the length of the elytron and the length of the posterior femur was the one almost exclusively adopted for studying the populations found in the different areas. The other ratios recommended by the III International Locust Conference were determined only when, owing to damage to either the elytron or the femur, the E/F ratio could not be determined. Although it was established that all the different ratios showed definite variation values, indicating the position of a specimen from the phase point of view, it was not known whether all the other ratios showed variations parallel to the E/F ratios. In order to study the actual relationship between the different ratios, numerous specimens were examined by the writer carefully determining the different ratios in every case. The results have been tabulated and arranged according to the E/F ratios in an ascending order and have been grouped under (1) *solitaria*, (2) *transiens*, and (3) *gregaria*, in *Statement B.R.I.* In this table, a new ratio C/O—which stands for the relation between maximum width of head (C) and width of head at the eye region (O), which will be dealt with at a later stage, is also included for comparison. It is seen that as the E/F ratios rise from 1.88 (at the bottom of the *solitaria* ratios) to 2.32 (at the top of the *gregaria* ratios), there is a fall from 1.617 to 1.243 in the P/C ratios, a similar decrease from 0.888 to 0.705 in the M/C ratios, and from 1.258 to 1.040 in the H/C ratios. In regard to the C/O ratios it is seen that, while they are below 1.10 in the *solitaria* and *transiens* groups, they are above 1.10 in the *gregaria* groups. It is obvious, however, that the variations do not run parallel to that of the E/F ratios, nor is there any close linkage between the other ratios, in the shape of any kind of correlation among themselves. The averages calculated for the different ratios, however, agree fairly with the figures arrived at by Zolotarevsky [in Vayssiere and Lepesme—1939].

Phase	E/F	P/C	M/C	H/C
Solitaria	2·05	1·47	0·88	1·21
Gregaria	2·23	1·28	0·77	1·06

In order to find out the degree of structural variation of the body due to phase difference among locusts of approximately the same size, six sets of specimens of each phase—three of males and three of females—were selected and carefully measured by Gupta. The results are given in Statement B.R. II.

From this statement, it is apparent that given the same length of elytron (which would practically be tantamount to equal length and size of body), the *gregaria* type has a much *shorter femur*, often a *slightly shorter pronotum* and always a *greater width of head*. The ratios E/F and P/C seem for that reason to be more significant than the others. Uichanco and Gines [1937], after an exhaustive examination of a large mass of material, came to the conclusion that, in *Locusta migratoria manilensis* Mey., the length of the tegmen is quite constant in both sexes, but the length of the hind femur is variable. The varying values of E/F are therefore the result of an increase or decrease in absolute length of the hind femur rather than of a change in the dimension of the tegmen. Since, however, they were dealing wholly with material collected from swarms and did not find any *solitaria* among the collections, perhaps their conclusions may not hold good in the case of non-swarm material.

In the course of the biometrical work, several instances were met with, in which the right femur differed from the left one in length, and similarly there were differences between the right and the left tegmina. The following cases are given to show the extent of the variation:—

1. No. 4335: Male; Kan Barar, 15-x-37; 6 str.; 27 ant. segments; Left Elytron: 53·3 mm: Right E. 52·0 mm: Right Femur 24·9 mm; Left F. 25·0 mm; so that the E/F ratio for the left side was 2·13, and for the right 2·09.

2. No. 5224: Male; Ormara, 25-ii-38; 7 str.; 28 ant. segm.; right F. measured 26·6 mm, and left F. 28·6 mm. The Elytron was 56·6 mm, so that the E/F ratio was 2·13 by the right F. and 1·97 by the left. As the P/C ratio was 1·379, 2·13 was taken to be the correct E/F.

3. No. 6311; Male; Sigak, 17-ix-38; 6 str.; 27 ant. segm; E. 49·0 mm; right F. 23.7 mm, left F. 21.3 mm, so that the right E/F was 2·07; and the left 2·30. It was evident, however, the form was *not gregaria* on other characters.

4. No. 1332: Female; Pishukan-Gwadar, 17-ii-36; 6 str. Left E/F: 53·7/27·6, equal to 1·95; and the right E/F was 58·.1/26·8 equal to 2·17. The right E/F was deemed to be the correct one, as the left elytron was evidently deformed.

In the course of biometrical work, various groups of locusts whose affinities it was important to determine came up for examination, but as many of them had either lost their femora or had the tips of the tegmina broken, it was difficult to determine their E/F ratios. Although it was possible to determine the pronotal ratios and thus fix the phase of the specimens, there was no possibility of correlating them with E/F ratios. As it appeared, however, possible that in cases where merely the tips of the elytra were broken, to find an easily recognizable landmark among the veins of the tegmen, various points likely to be useful for the purposes of measurement were examined and tested. Eventually, the point where the anal (or vannal) area ends on the posterior margin of the elytron was found the most suitable for determining the position of the specimen on the E/F scale, since the length of the elytron up to the tip of the anal area was found to bear a definite relation to the length of the entire fore-wing. It is proposed to call this point the 'Vannal Apex' or 'Vannal Tip', and the new ratio—which is determined in exactly the same manner as the E/F ratio—the V/F ratio.

STATEMENT B. R. No. III

Relationship between E/F and V/F Ratios

Locality	Date of collection	Eye Stripes	Sex	*E*	*V*	*F*	E/F	V/F	E/V
				Year 1930					
Dalbandin	VII	6	♂	51·7	39·2	23·5	2·20	1·67	1·32
Dalbandin	III	?	?	58·6	44·3	26·0	2·25	1·70	1·32
				Year 1931					
Quetta .	28-VI	6	♀	59·2	45·1	26·5	2·23	1·70	1·31
Dalbandin	V	?	♀	58·6	44·4	26·5	2·21	1·68	1·315
Ahmedwal	V	?	♂	51·8	39·0	23·4	2·21	1·66	1·33
Pasni .	23-V	6	♂	56·1	43·0	25·2	2·22	1·70	1·305
,,	25-XI	6	♂	52·3	40·0	23·7	2·20	1·68	1·31
,,	23-V	6	♀	61·6	46·1	27·2	2·26	1·71	1·34
Dalbandin	V	6	♀	58·5	44·4	26·5	2·21	1·68	1·32
Dasht .	12-VI	6	♂	52·5	40·3	23·6	2·22	1·70	1·31
Loralai .	3-VIII	6	♂	49·3	38·4	22·6	2·21	1·70	1·30
Pasni .	24-IX	6	♀	60·3	45·2	26·4	2·28	1·71	1·33
Panjgur .	6-X	6	♀	53·9	40·7	24·7	2·18	1·65	1·32
				Year 1932					
Pasni .	III	6	♂	55·9	42·5	24·7	2·25	1·72	1·31
,, .	III	6	♂	55·9	42·5	24·8	2·25	1·71	1·32
,, .	VIII	6	♂	54·0	41·3	25·2	2·14	1·63	1·31
,, .	IX–XI	7	♂	51·2	38·6	26·7	1·91	1·45	1·32
,, .	I-III	7	♀	61·4	46·5	30·3	2·02	1·54	1·31
,, .	I-III	6	♂	56·1	42·8	26·0	2·15	1·64	1·31
Kolwah	14-IX	6	♀	60·8	46·5	29·9	2·03	1·55	1·31
,, .	14–IX	6	♂	53·7	41·0	25·6	2·09	1·60	1·31
,, .	10-14–IX	6	♂	52·9	40·2	23·9	2·21	1·68	1·315
Mekran .	10-14–X	7	♀	59·9	45·5	29·8	2·00	1·53	1·31
,, .	10-14–X	6	♂	52·3	39·6	24·3	2·15	1·63	1·32
Hor-Kalat	15-IX	6	♂	52·7	41·0	25·4	2·07	1·57	1·32
Mand .	9-II	6	♀	58·2	44·2	25·4	2·28	1·74	1·315
Nasirabad	12-II	6	♂	53·2	41·3	24·6	2·16	1·68	1·29
Gwadar .	1-II	6	♀	63·6	48·0	29·1	2·18	1·65	1·32

Locality	Date of collection	Eye Stripes	Sex	*E*	*V*	*F*	E/F	V/F	E/V
Mand .	1-II	6	♂	53·8	41·5	25·2	2·14	1·64	1·305
Khairpur .	17-VI	6	♀	56·6	42·8	26·1	2·16	1·64	1·32
,, .	19-VI	6	♀	60·8	46·5	29·9	2·03	1·55	1·31
Kolwah .	14-IX	6	♀	60·8	46·6	29·9	2·03	1·55	1·31
Mekran .	14-IX	6	♂	51·0	38·2	24·3	2·10	1·57	1·325
Ambagh .	XI	?	♀	64·1	48·2	31·8	2·01	1·50	1·34
,, .	XI	6	♀	64·7	50·2	31·4	2·06	1·60	1·29
				Year	*1934*				
Hairokhan .	21-IV	6	♂	48·2	36·7	23·2	2·07	1·58	1·31
Chachro .	VIII	7	♂	58·2	44·0	28·1	2·07	1·56	1·32
,, .	20-IX	6	♂	52·1	40·0	25·7	2·03	1·55	1·31
,, .	10-IX	7	♀	61·4	46·7	30·2	2·03	1·54	1·32
,, .	27-XI	6	♂	52·3	40·1	26·2	2·00	1·53	1·31
Khisar .	24-X	7	♀	67·5	51·2	33·6	2·00	1·52	1·315
Chachro .	14-X	7	♂	52·6	40·7	27·2	1·93	1·47	1·315
Hingol .	IX	6	♀	51·8	39·5	23·9	2·17	1·65	1·315
Ambagh .	1-III	7	♀	61·7	47·5	29·2	2·11	1·62	1·305
Pasni .	7-VII	6	?	52·7	40·8	25·6	2·06	1·59	1·295
Tarcharnor.	12-VII	6	♂	54·3	41·3	26·2	2·07	1·57	1·32
Chachro .	VIII	7	♀	64·0	48·4	33·2	1·92	1·45	1·325
Jang Shahi.	16-IX	6	♀	61·6	47·6	28·8	2·14	1·65	1·30
Bhadka .	28-IX	7	♀	65·3	50·2	33·5	1·95	1·49	1·31
Chachro .	VIII	7	♀	59·9	45·6	28·8	2·07	1·58	1·31
,, .	VIII	7	♀	64·8	49·3	32·5	2·00	1·51	1·325
,, .	VIII	6	♂	52·1	40·1	25·1	2·07	1·59	1·30
,, .	VIII	7	♂	55·7	42·2	28·1	1·98	1·50	1·32
				Year	*1935*				
Ambagh .	3-II	?	♀	60·9	46·4	31·2	1·95	1·49	1·31
Sonmiani .	XI	?	♀	62·1	48·6	31·2	1·99	1·56	1·32
Ambagh .	3-XI	?	♂	54·4	41·8	25·1	2·17	1·67	1·305
,, .	28-XI	?	♀	61·3	46·1	27·1	2·21	1·66	1·33
Chachro .	24-II	7	♀	62·0	47·4	31·9	1·94	1·48	1·31
,, .	22-V	6	♀	58·4	44·2	27·1	2·15	1·63	1·32
,, .	25-IV	?	♂	50·7	38·4	24·6	2·06	1·56	1·32

Locality	Date of collection	Eye Stripes	Sex	*E*	*V*	*F*	E/F	V/F	E/V
Shashtal .	7-VII	?	♂	46·6	35·1	23·7	1·96	1·48	1·325
Pasni .	15-I	?	?	65·8	49·7	32·6	2·01	1·52	1·325
Nakhetri .	IV	6	♀	59·5	46·0	27·7	2·20	1·66	1·325
Nakakharari	20-X	6	♀	61·3	46·6	27·8	2·20	1·67	1·33
Ormara .	1-13-X	?	♂	57·3	43·2	24·8	2·31	1·74	1·33
Ambagh .	28-VII	?	♀	61·3	46·1	27·7	2·21	1·66	1·33
,,	30-VII	?	♀	57·8	44·6	28·8	2·00	1·55	1·29
Nakakharari	30-XI	6	♀	62·3	47·5	27·8	2·24	1·70	1·32
,,	,,	6	♂	51·5	39.1	23·6	2·18	1·65	1·32
,,	,,	?	♀	59·1	45·8	30·1	1·96	1·52	1·29
,,	,,	?	♀	64·5	48·6	30·8	2·09	1·57	1·33
				Year 1936					
Chachro .	18-IV	6	♀	58·2	43·7	28·9	2·01	1.51	1·33
,,	26-V	6	♂	53·1	40·5	26·1	2·03	1·55	1·31
,,	27-V	7	♂	51·2	40·2	26·2	1·95	1·53	1·275
,,	30-V	7	♀	65·7	50·1	32·4	2·03	1·56	1·30
,,	1-VI	7	♀	61·1	47·7	29·8	2·05	1·57	1·31
,,	30-V	6	♂	52·8	40·6	26·0	2·03	1·56	1·30
,,	31-V	7	♂	52·7	40·6	25·2	2·13	1·61	1·32
Muro (Chambarkalat) .	31-III	6	♂	51·8	39·2	25·5	2·03	1·55	1·31
				Year 1937					
Tash-i-Daf .	26-III	6	♂	51·9	39·4	26·3	1·97	1·50	1·315
Ban . .	15-VI	6	♂	45·8	34·3	22·4	2·04	1·53	1·33
Nokbur .	25-VI	7	♀	58·9	44·8	30·1	1·96	1·48	1·325
Suntsar .	23-X	6	♀	53·9	40·6	26·1	2·05	1·56	1·315

[*Text Figr.* 17 (1) *and* (2), *showing venation of tegmen*].

Imms [1930] gives a good text-figure to illustrate the venation of *Schistocerca* and Karandikar [1939] has given a good description of the venation of the tegmen and wing of the Desert Locust. In the figures given (Fig. 17, 1 & 2) the points utilized for making biometrical measurements have been clearly shown. In measuring the length of the forewing, it has been, in most cases, found difficult to reach the base of the tegmen, as it is generally hidden under the metazonal flaps, and Zolotarevsky [1929] has fixed the hollow of the angle formed by the costa and the sub-costa, as the proximal point for measurement, the distal one being the extreme tip of the elytron.

The common base of the costal and sub-costal veins takes the form of a knob-like protuberance and forms a prominent land-mark not likely to be missed by workers, though at times, especially when examining specimens with closed wings, another raised area marking the basal parts of the anal and cubital veins is liable to be mistaken. The anal (or vannal) area of the tegmen is an elongated triangular strip which covers the dorsal surface of the body of the locust when at rest, in which position the *anal area* of the tegmen of one side overlaps that of the other. In a position of rest, the pre-anal area of the tegmen bends downwards, forming an angle with the *anal area,* and covers the sides of the body. The *anal area* is supported by (1) the 1st anal vein which with its parallel nervures extends to the apex of the area, and (2) by the 2nd anal vein which stops short about half way without reaching the margin. At the region of the bend of the anal area, two veins are placed closed together *viz.* the 1st anal, and the post-cubitus and its branch, while the flanks of the pre-anal area of the tegmen are supported by the cubitus, the cubito-median cross-vein and the two branches of the second median vein. In most cases, the two branches of the second median vein tend to reunite near the posterior margin at a point close to the tip of the vannal area, but in some instances, the apex of the latter may run beyond the tip of the second median area (Fig. 2), or rarely the latter may outrun the former.

In the new ratio—V/F, one of the points is, as in the E/F ratio, the angle formed by the costa and sub-costa, and the other is the tip of the 'Vannal area' (V in Fig. 1). In the case figured, the tip of the second median area also reaches very nearly the same distance. In those cases, however, where the tips of the vannal and the median areas are not equidistant from the costal angle, a point midway between the two tips is taken for the purpose of V/F measurements (Fig. 2). In all those cases, in which the tips of the elytra are damaged, the vannal apex is usually left entire, so that it is always possible in such cases to determine the phase characters, if the femur is available for measurements.

Table B.R.-III gives a list of biometric measurements of a large series of undamaged specimens, in the case of which both E/F and V/F ratios were worked out for purposes of comparison. Since the E/F and V/F ratios are both based on the length of femur (F), the relationship between the two ratios is the function of E/V. From the results tabulated in the last column, it is seen that the function varies between 1·30 to 1·33 on the whole, and in the majority of cases it is between 1·31 and 1·32. If the V/F ratio is determined, E/F ratio would probably lie between V/F×1·31 and V/F×1·32.

STATEMENT B.R.-IV

An Analysis of the Relationship between Ratios E/F and C/O in Schistocerca gregaria

SOLITARIA RATIOS 1·88 TO 2·05									
MALES					FEMALES				
Locality	Date	Eye-Stripes	E/F	C/O	Locality	Date	Eye-Stripes	E/F	C/O
Chachro	14-v-34	7	1·93	1·04	Chachro	viii-34	7	1·92	1·08
,,	viii-34	6	1·94	1·02	,, .	20-v-06	7	1·93	1·09
,,	27-v-36	7	1·95	1·06	,, .	24-ii-35	7	1·94	1·08
,,	7-iv-36	6	1·96	1·04	Ambagh .	3-ii-34	?	1·95	1·09
Islamkot	22-x-32	6	1·96	1·09	Bhadka .	28-ix-34	7	1·95	1·09
Chachro	18-viii-34	6	1·98	1·09	Somniani .	xi-35	?	1·99	1·08
Kolwah	10-14-ix-32	6	1·98	1·06	Kolwah .	14-ix-32	6	1·99	1·06
Chachro	30-v-36	6	1·98	1·05	Diplo .	17-x-32	7	1·99	1·04
,,	10-iv-36	6	1·99	1·05	Khaisar	24-x-34	7	2·00	1·06
Mandvi	6-v-34	7	1·99	1·05	Mekran .	10-14-ix-32	7	2·00	1·05
Chachro	27-xi-34	6	2·00	1·04	Chachro .	viii-34	7	2·00	1·10
,, .	9-iv-34	6	2·00	1·03	,, .	viii-34	7	2·00	1·05
Pasni .	viii-32	6	2·01	1·09	,, .	11-vi-36	6	2·00	1·05
Chachro	3-iv-36	6	2·01	1·09	Khisar .	24-v-34	7	2·00	1·06
Pasni .	viii-32	6	2·02	1·09	Chachro .	18-iv-36	6	2·01	1·08
Chachro	26-v-36	6	2·03	1·08	,, .	9-vi-36	7	2·02	1·05
,,	28-iv-36	6	2·03	1·03	Ambagh	24-x-33	?	2·02	1·10
,,	30-v-36	6	2·03	1·05	Lathi .	29-xi-32	7	2·03	1·09
,,	20-ix-34	6	2·03	1·03	Kolwah .	14-ix-32	6	2·03	1·08
,,	10-ix-34	7	2·03	1·10	Chachro .	16-viii-34	?	2·03	1·05
Ormara	10-viii-32	6	2·05	1·04	,, .	30-v-36	7	2·03	1·12
Chachro	14-x-34	7	2·05	1·01	,, .	20-ix-36	7	2·03	1·03
					,, .	1-vi-36	7	2·05	1·10
TRANSIENS 2·06 TO 2·15									
Chachro	25-vi-35	?	2·06	1·05	Chachro .	viii-34	6	2·07	1·07
Mekran	10-14-ix-32	6	2·07	1·06	,, .	20-v-36	7	2·07	1·08
Hor Kalat	15-ix-32	6	2·07	1·04	,, .	10-vi-36	6	2·09	1·05
,,	14-ix-32	6	2·07	1·04	Mand .	9-ii-32	7	2·09	1·10
Kolwah	14-ix-32	6	2·07	1·05	Chachro .	4-vi-36	6	2·10	1·08
Hairokhan	21-iv-36	6	2·07	1·05	Chapur-Khosa	2-xi-34	6	2·10	1·07
Chachro	23-vi-34	7	2·07	1·04	Chachro .	8-iv-36	6	2·11	1·09
Tarcharnor	12-viii-34	6	2·07	1·06	Chachro .	17-ii-36	6	2·13	1·09
Chachro	viii-34	7	2·07	1·03	Mand .	8-ii-32	6	2·14	1·13

TRANSIENS RATIOS 2·06 TO 2·15 (*contd.*)									
Kandasole	8-ii-35	?	2·07	1·06	Jhimpir	16-ix-34	6	2·14	1·12
Gwadar	31-i-32	6	2·08	1·10	Mehrabpur	18-vi-32	6	2·14	1·14
Chachro	4-vi-36	6	2·08	1·05	Pasni .	viii-32	6	2·15	1·16
Kolwah	14-ix-32	6	2·09	1·08	Chachro	22-v-35	6	2·15	1·08
Mand .	9-ii-32	6	2·09	1·06	Paburjo-Tur	1-xi-34	6	2·15	1·10
Chachro	31-v-36	7	2·09	1·03					
Mekran	14-ix-32	6	2·10	1·06					
Chachro	11-vi-36	6	2·10	1·03					
,, .	13-vi-36	6	2·10	1·05					
Mand .	9-ii-32	6	2·11	1·13					
Chachro .	24-vi-36	6	2·11	1·09					
Chang	19-vi-32	6	2·12	1·11					
Chachro .	11-vi-36	6	2·12	1·06					
,, .	13-vi-36	6	2·12	1·09					
,, .	11-vi-36	6	2·13	1·03					
Mand .	9-ii-32	6	2·14	1·09					
Mekran .	14-ix-32	6	2·15	1·14					
Mand .	8-ii-32	6	2·15	1·12					
GREGARIA RATIOS 2·16 to 2·32									
Nasirabad	12-ii-32	6	2·16	1·14	Ambagh .	3-ii-35	?	2·17	1·18
Ambagh .	3-xi-35	?	2·17	1·19	,, .	24-ix-35	6	2·17	1·15
,, .	3-vi-35	?	2·17	1·19	Mithi .	21-x-32	6	2·17	1·12
Mand	2-ii-32	6	2·18	1·11	Gwadar	i-ii-32	6	2·18	1·17
Pasni	viii-32	6	2·19	1·12	Panjgur	5-x-31	6	2·18	1·17
Mand	9-ii-32	6	2·20	1·17	,, .	5-x-31	6	2·19	1·17
Ormara	20-ii-32	6	2·20	1·17	Naka	4-ii-32	6	2·20	1·13
Suntsar	18-v-31	?	2·21	1·10	Ambagh .	28-viii-35	6	2·21	1·15
Pasni	23-v-32	6	2·22	1·14	Mand .	9-ii-32	6	2·20	1·13
Mand	9-ii-32	6	2·22	1·14	Khairpur Mirs	19-iv-32	6	2·22	1·13
Pasni	iii-32	6	2·22	1·19	Mand .	9-ii-32	6	2·22	1·14
,,	23-v-31	6	2·22	1·17	Lasbela	7-iv-31	6	2·22	1·19
Quetta	26-v-31	6	2·23	1·17	Gwadar	2-ii-32	6	2·23	1·19
Pasni	iii-32	6	2·25	1·17	Quetta .	28-vi-32	6	2·23	1·17
Mand	9-ii-32	6	2·27	1·16	Moro	12-vi-32	6	2·23	1·16
Pasni	viii-32	6	2·27	1·14	Turbat .	13-ii-32	6	2·24	1·14

GREGARIA RATIONS 2·16 TO 2·32 (*contd.*)

Pasni .	23-v-31	6	2·28	1·14	Turbat .	19-ii-32	6	2·24	1·14
Ormara .	1-13-x-35	6	2·31	1·12	Mand .	9-ii-32	6	2·24	1·14
Mand .	9-ii-32	6	2·32	1·16	Turbat .	13-ii-32	6	2·25	1·12
					Saidu .	vi-32	6	2·26	1·20
					Pasni .	24-ix-31	6	2·28	1·15
					Panjgur .	5-x-31	6	2·29	1·20
					Mand .	9-ii-32	6	2·29	1·16
					Moro .	12-vi-32	6	2·32	1·16
					Pasni .	i-iii-32	6	2·32	1·20
					Karachi .	22-iv-31	6	2·32	1·17

In the course of taking measurements of the various parts of the locust for the determination of the pronotal ratios, it was apparent that the width of the head was a fairly significant point for examination, since the increase in the width of the head at the genal region was particularly conspicuous in *gregaria* individuals. With the idea of finding whether this could be linked with any other character of the head so as to get a ratio which could give independently of the other parts of the body an indication of phase, an exhaustive examination was made, and the following character was selected as a fairly promising one. A comparison of the heads of specimens of the *phase solitaria* and *gregaria* showed that while there were clear differences in width at the genal region of the face, there were none in the region of the compound eyes. Comparing facial contours of *solitaria* and *gregaria*, a distinct bulge is seen in the cheeks of the latter, whereas the ocular outline was not dissimilar. In the course of biometrical measurements, a new ratio showing the relation between the maximum width of the face at the genal region (C) and the maximum width at the ocular region (O) was worked out along with the other ratios. Statement B.R. No. IV gives the results obtained, tabulated so as to show the relation between the E/F and C/O ratios arranged according to the sexes and the phases. It is seen therefrom that in the lower E/F ratios ranging from phase *solitaria* up to E/F 2·10 in phase *transiens*, C/O ratios show much individual variation ranging from 1·02 to 1·10, the tendency being for the females to have slightly higher ratios than the males. In the case of phase *transiens* above E/F 2·10, ratios higher than 1·10 are generally noticed, especially in the females, while in *phase gregaria*, the ratios are always higher than 1·10 and may range up to 1·20.

The general results of a biometrical examination of the mass of collections gathered in the course of locust surveys indicate that the whole material falls into a long series of forms showing a great variation of characters, with the extreme types—*solitaria* and *gregaria* at either end, connected by an infinite gradation of intermediate forms between them. The desert locust, as a species, may be likened to a mass of plastic material, which yields to the moulding action of its environment in varying degrees and in different ways. In extreme *gregaria*, sharp differences are noticeable as compared with *solitaria* forms, in various characters such as longer elytra, shorter femora, a bulge in the cheeks, a depression in the crest of the pronotum, a shortening of the prozona and a constriction in the prothorax. In the intermediate forms, changes may be manifested in only one or two of these characters, and the transition from the *solitary* to the *gregarious* does not occur as a continuous gradation involving all the characters. Variations in the different characters do not appear to be

linked together, but to occur independently. A locust having a particular E/F ratio need not necessarily be in the same state of development from the point of view of the other ratios, although an extreme gregaria form like extreme *solitaria*, may exhibit typical developments of all the various characters. Since E/F has proved to be the most expressive and significant ratio, changes in the phase characters have been shown in many cases in terms of this ratio in working out the biometrical facies of locust population in preference to the others.

Eye-stripes and antennae in biometrical work

The various characters that serve to differentiate the phases of the locust are the effects of the nature of life led during the hopper period. The *gregaria* characters are, for instance, brought about as a result of crowded breeding among hoppers, or at least an active larval life [Husain and Mathur, 1936], whereas the *solitaria* ratios are the effect of hoppers leading an isolated life. On the other hand, the number of eye-stripes in the adult locust has been shown in a previous chapter (sec. III, Chapter 1) to be dependent on the number of instars passed through in the hopper period. In the case of the number of antennal segments also, Mukerji [1938] has shown that they vary with the number of larval moults. The eye-stripe character (sometimes in conjunction with the antennal) has been utilized in determining the biometrical index of populations.

Eyestripes. Since Roonwal [1936] pointed out the existence of two types of eye-stripes among locusts found in nature on the Mekran coastal areas, one having six and the other seven stripes, both types have been found, commonly in the non-gregarious type of locust populations found in many parts of the Indian area. In the case of locusts collected from swarms, whether during the last great infestation or in past cycles, the number of stripes was found to be invariably six in all cases where eye-stripes could be distinguished. On the other hand, several specimens with eight-stripes were collected from nature in 1936. In addition, individuals with five stripes in the eyes—often with full-developed wings have been reared out in the course of rearing experiments, though none of the five-striped type has so far been collected in the field. As may be seen from the figures of all the four different types of striped eyes [*vide* Text Fig. 18 (1-4)], there is little difference except in the number of stripes, though in many cases, there is apparently a tendency for the first two or three anterior stripes in the six-striped as well as the seven-striped types to be a little thicker than the posterior ones.

In this connection, it may perhaps be pointed out that the inter-stripes mentioned by Roonwal [1936] and Mukerji [1938] as occurring between the stripes are not really separate entities like the 'stripes', but merely form, along with the 'anterior' and the 'posterior spaces', the opaque greyish white background of the eye in which the stripes and the dorsal spot are set. In the brownish unstriped eyes of cage-bred gregarious type adults, the grey background is found to have disappeared, but when exposed to the sun, the greyish background reappears gradually, being first noticed as thin grey streaks (the so-called inter-stripes), which ultimately unite together to bring the brown stripes into relief. On the other hand, in certain bluish green type of hoppers found on bushes of *Aerua tomentosa*, the background—which is noticed in this type to be a greyish blue—is seen to have spread over the whole eye, and the eye-stripes are found as thin scarcely noticeable brown streaks.

Antennae. As the number of antennal joints of specimens has been found of significance in determining the eye-stripe characters in doubtful cases, a study of the antennae in the desert locust was made. So far as

the writer is aware, the antenna of the locust is usually described as consisting of two basal joints—the *scape* and the *pedicel*—and a *flagellum* made up of 24 to 25 articulated segments. A careful examination of the flagellum would show that it is made up of three distinct divisions: (1) the 'club' or 'flagellar tip' at the distal end, (2) the 'funicle', and (3) the proximal region of active growth. The 'club' is formed of a clearly marked group of four very short joints, which is distinctly separated from the rest of the flagellum by a fairly marked constriction. The funicle consists of 15 joints of which the one next to the 'Club' is very short and the rest are long—about two to three times as long as broad, and the proximal part of the flagellum is made up of a varying number of joint, mostly short, being about as long as broad. An examination of the drawings (Text Fig. 19) of the five types of antennae figured, *viz.*: those with 26 and 27 segments—found in locusts with six-eyestripes, those with 28 and 29 segments—in the seven-striped individuals, and the one with 30 segments in the eight-striped ones, indicates that the difference in the number of joints in these five types is due to the variations in the number of segments in the basal region, the number being 5, 6, 7, 8 and 9 respectively in these types. An explanation of these variations has to be sought in the differences in the post-embryonic development in these types. Uvarov [1928] has reproduced Takahashi's drawings showing the post-embryonic growth of the antennae in the Migratory Locust, the development of which would appear to be parallel to that of the Desert Locust. The 'club' at the tip as well as the scape and the pedical would appear to be present in the I instar, in which 13 joints are noticeable. In the II instar, six of the intermediate joints divide into two each, making the number of segments 19. In each succeeding moult, two more joints are added so that the number of segments in the III, IV and V instars is 21, 23 and 25 respectively, and in the adult of the 5-instar type the number should be 27 normally. However, as shown by Takahashi, only one segment may be added in the III moult in certain types of hoppers, so that the total number of joints in the IV instar would then be 22 instead of 23, and consequently only 26 in the adult instead of 27. In the six-instar type hopper development, the number of joints in the antennae would, thus, be 28 or 29, and in the seven-instar type, 30 or 31. Mukerji [1938] has shown that the number of segments in the type with 5-eye-stripe is ordinarily 25.

Relation of the number of antennal joints with eye-stripes and E/F ratios

In order to find the order of distribution of the different E/F ratios among the individuals with the different antennal types, Gupta made an extensive examination of a large series of specimens with the following results:—

STATEMENT-B.R.-V

Number of specimens examined

A. *Specimens with six-eye-stripes.*

Total number examined—873.

1. Specimens with 26-segmented antennae—61.
2. Specimens with 26-27 segments (*i.e.*, including a partially divided segment)—50.
3. Specimens with 27-segmented antennae—762.

B. *Specimens with seven-eyestripes*

Total number of specimens—517.

1. Specimens with 28-segments—438.
2. Specimens with 28-29 segments (*i.e.*, including one half-divided segment)—21.
3. Specimens with 29 segments—58.

An analysis of the distribution of the different antennal types in relation to Eye-stripes and the E/F ratios.

Type of	Specimens	*Solitaria*		*Transiens*		*Gregaria*		E/F not known	Percentaege of phass
		Bolow 2·00	2·00 2·05	2·06 2·09	2·10 2·15	2·16 2·19	2·20 and above.		S : T : G
Eye-stripes	Antennal joints.								
A. Type with Six-eye-stripes	With 26 joints.	Nil	Nil	3	10	16	24	(8)	0 : 25 : 75
	with 26-27 joints	Nil	7	8	17	6	8	(4)	15 : 55 : 30
	with 27 joints.	111	270	167	130	17	8	(59)	54 : 43 : 3
B. Type with Seven-eye-stripes.	With 28 joints.	123	180	75	20	6	Nil	(34)	75 : 24 : 1
	with 28H 29 joints	9	4	3	4	Nil	Nil	(1)	65 : 35 : 0
	with 29 joints	26	27	2	Nil	Nil	Nil	(3)	96 : 4 : 0

From the above, it may be noted that among the forms with six eye-stripes, those with 26 antennal joints or with 26-27 joints (*i.e.*, including one partially divided joint) generally have high E/F ratios, mostly *gregaria and transiens*, while those with 27 joints have lower ratios, mostly *solitaria* and *transiens*. On the other hand, among the seven-striped type the vast majority are *solitaria* forms with 28 joints, though they sometimes include a few rare *gregaria* specimens near *transiens*, they are mostly either *solitaria* or *transiens* near *solitaria*, while the 29-*jointed* forms are mostly *solitaria* of low ratios.

In the course of an examination of collections of *Locusta migratoria* from various parts of N. W. India, Gupta [1939] found that the number of antennal segments varied from 26 to 29. He has recorded 26-28 segments for *gregaria* and *transiens* forms, and 27-29 *solitaria* forms. As this species does not show stripes in the eyes, it is not possible, to say definitely whether these differences in the number of antennal segments similarly connote variations in the number of larval moults, though doubtless it is highly probable, since it is known that, as a rule, two new segments are added at each moult from the third instar onwards.

In regard to specimens with eight eye-stripes, measurements have been recorded in the case of nine individuals, out of which seven had E/F ratios varying from 1·94 to 2·00, and two showed *transiens* ratios, 2·08 and 2·11. The number of antennal segments were recorded in three cases:—a specimen with E/F 2:11 had 30 segments, and two with low *solitaria* ratios 1·99 and 2·00 had 30-31 and 31 segments.

Biometrical facies of locust populations

General observations made in the field in the course of locust surveys carried out during the years 1931—1938 have shown that locusts are being continuously affected by changes in the environment. There may occur, as the result of local breeding and multiplication, not only an increase in numbers, but also a change in the phase of the population, according to the character of the breeding. A similar change in the composition of the population may take place in the event of an immigration from outside. In estimating the character of locust population, reliance cannot be placed on coloration by itself, as it is liable to change. It should be based on a careful biometrical examination of sample collections. If the results indicate mainly a *solitaria* facies, the inference would be that there is no immediate danger of swarming; on the other hand, if there should be a fair proportion of *gregaria*, it may be taken as an indication of tendencies for grading up and forming concentrations that may lead to incipient swarming if the conditions are favourable.

The third International Locust Conference recommended that the average ratio of populations should be obtained, not by calculating the average of individual ratios, but by working out the ratio of the totals of the measurements. Although average ratios are useful in simplifying a comparison between different populations, they do not convey any idea of the extent of variation in regard to phase development that may be observable in any given population at a particular time and place. In some cases, it is the extent of variation that is of greater significance than the relative value of the mean ratio. For instance, the presence of a small percentage of individuals with high *gregaria* ratios among an otherwise mainly *solitaria* population is of particular importance in evaluating its character, but this circumstance cannot be conveyed in terms of the average ratio. The phase variations could be expressed best by tabulating the actual number of individuals in gradations of E/F ratios of the value of 0·05 as done by Zolotarevsky [1938]. The frequency distribution of E/F ratios of similar value among the population can also be represented in graphs, as was, for example, done by Kennedy [1939]. In both cases the range and size of variation can be evaluated at a glance.

In the present study, a different method of showing graphically the constitution of a population met with at any given place and time has been adopted as already explained in a previous chapter (Sec. III Ch. 1). Based on the results of a biometrical examination, the population is grouped under three categories *solitaria, transiens* (or intermediate) and *gregaria* according to their E/F ratios, and it is also further grouped according to the number of eye-stripes possessed by the individuals, into the 6-stripe and the 7-stripe types.

In regard to the phase characters, it has been found from the examination of specimens collected from flying swarms that the great majority of them possess E/F ratios above 2·16 reaching up to 2·34. On the other hand, the great majority of the non-gregarious type of locusts found in the rek or desert areas in the Indian region were on examination seen to have E/F ratios below 2·05, usually varying between 1:88 and 2:00. Besides, these various forms with ratios intermediate between *solitaria* and *gregaria*, usually possessing general characters approximating either *solitaria* or *gregaria*, are also found in varying numbers. Though it is

not possible to fix any rigid limit between the phases in nature, an arbitrary division of the series of E/F ratios, has been made for the purpose of classifying locust populations, under the following three categories: (1) *solitaria*—2·05 and below; (2) *transiens*—2·06 to 2·15; and (3) *gregaria*—2·16 and above. Murat (1939) in the course of a biometrical examination of *Schistocerca* material, found that *gregaria* ratios determined from a series of specimens belonging to flights of 1933 in Spanish Sahara ranged from 2·16 to 2·44 in females and from 2·17 to 2·28 in males. He also found ratios ranging from 1·95 to 2·04 among individuals collected in the solitary phase stage in Spanish Sahara. His results would appear to amply support our findings.

On the basis of the number of individuals found under (1) the phase groups of *solitaria*, *transiens* and *gregaria*, and (2) under the eye-stripe groups, percentages are calculated, and the biometrical 'facies' or 'index' of the population concerned is shown in terms of the proportions noted under the phase and eye-stripe characters in the following form:—*S*: *T*: *G*: : (6): (7). This method may be claimed to give at a glance the state of development of the population at any particular time or place from the view point of phase, and has, moreover, been useful in identifying populations in different areas and in tracing the movements of non-gregarious locusts. For example, the population found on the Mekran reks in January-March 1935 (based on 79 specimens) had the index:—76*S*: 23*T*: 1*G*: : 34(6): 66(7), whereas in April-May 1935, the facies based on 55 specimens was: 62*S*: 29*T*: 9*G*: : 67(6): 33(7). On the other hand, the facies of the locust population on the Mekran reks after the locust incursion in July (based on 154 specimens) was as follows:—24*S*: 35*T*: 41*G*: : 88(6): 12(7). The decrease of the proportions of *solitaria* ratios and 7-*stripes* and the increase of *gregaria* and 6-*stripes* between January and July is striking. Similarly, the facies of the immigrant population in the Sind-Rajputana area in July 1935, based on an analysis of 279 specimens, was:—28*S*:43*T*: 29*G*: :92(6): 8(7), which shows its affinities with the incursion population of Mekran. On the other hand, the index of the new brood found in October-November 1935 in the desert, based on 288 specimens, was 69*S*: 30*T*: 1*G*: :29(6):71(7). The population found in the Lasbela area in December, 1935, based on an examination of 22 specimens, indicated the facies:—59*S*: 41*T*: 0*G*: : 64(6): 36(7). These data show that there was a complete change of phase during the monsoon breeding in the desert, and also indicate an affinity between the desert brood and the autumn immigrants in the Lasbela area.

In working out the biometrical index, it is advisable to have as large a series of specimens as possible to secure an accurate estimation of values. As a general rule, each batch of population should contain at least 100 specimens for the purposes of analysis for obtaining reliable results, and the larger the number, the better. Very often, however, only small numbers are seen in the field, and sometimes it is not possible to secure a good series of specimens, and in these cases one has to make the best of the available material. In the course of the present studies, however, it has been found that even with as small a number as 20 or 25, fairly definite indications of the main characters of a population can be obtained. In some cases, as few as 8 or 10 have been utilized for this purpose, though of course, the reliability of the results is questionable.

In regard to the eye-stripe character, there is abundant evidence that the large majority of the males are linked with the 6-stripe character. It is only at the peak of *solitaria* development that a fair number of males with 7 eye-stripes are met with. On the other hand, at this time quite a large proportion of the females are of the 7-striped type. When ratios are on the up-grade and large numbers of *transiens* are noticed, females with

six-stripes begin to be increasily noticeable. It may perhaps be a better method to restrict the percentage calculation in regard to the stripes to the females only. Even in regard to phase, there would appear to be differences in the development of E/F ratios between the males and the females. Du Plessis [1939] found the mean E/F ratios of the females significantly higher than those of males in *Locustana pardalina*. Zolotarevsky and Murat [1938] similarly noticed that the mean ratios for females were higher than those for the males in the solitary phase forms of *Schistocerca gregaria*. In the present studies, however, this aspect has not been examined, but for all practical purposes the differences between males and females do not appear to be high enough to be of much significance in affecting the value of the biometrical index.

E/F Ratios in other Locusts

In the desert locust, the E/F ratios have been grouped as already mentioned, under *solitaria*—2·05 and below; *transiens*—2·06 to 2·15; and *gregaria*—2·16 and above. The lowest ratio noted was 1·64.

Similarly, on the results of a biometrical examination of material collected in north-west India in 1936-37, a grouping of E/F ratios for *Locusta migratoria* found in the Indian areas, into similar phase grades as shown below was attempted by Rao and Bhatia [1939]:—*Sol.* 1·90 and below; *Tran.*—1·91 to 2·00;—*Greg.* 2·01 and above. In the case of *Patanga succincta*, a fair number of specimens collected in the desert areas occurring as solitary individuals were examined, and in addition, some of the forms collected from swarms, found in the collections of the Imperial Entomologist, New Delhi, were examined in 1937. On the basis of the results of this rather preliminary work, it may be stated that (1) the *solitaria* ratios probably lie below 1·82. In one case, E/F 1·64 with 31 antennal segments was noted. Eye-stripes were usually 8; in a few cases 9 stripes were noted. The antennal segments were 30 or 31. (2) *Gregaria* ratios were found ranging from 1·85 to 1·97. The usual number of eye-stripes was 8, and the antennal joints ranged from 28 to 30. One specimen collected in 1933 from Mandvi, Cutch State, was found to be rather thick-set. The elytra were short and as the femora had been lost, the E/F ratio could not be determined. There were 7 eye-stripes and 28 antennal joints. Several specimens of this description, collected from the Murree Hills, were found in the collections of the Imperial Entomologist, which had also 7 stripes and 27 antennal segments, and in two cases E/F ratios of 1·70 and 1·73 were worked out. It may be of much interest if the organic connexion between these thick-set forms* with 7 stripes and the normal forms of *Patanga* with 8 stripes and longer elytra, can be worked out.

In respect of the Red Locust of Africa (*Nomadacris septemfasciata*), Zolotarevsky [1939] found the *solitaria* ratios ranging from 1·64 to 2·00, and the *gregaria* ones from 1·99 to 2·24. In the case of the typically solitary grasshopper, *Cyrtacanthacris tatarica*, the writer found ratios 1·40 to 1·73 in a few specimens examined.

Notes on Biometrical work published since June, 1941

Thomas [1941] working on the relative size of the compound eye as a phase character in *Locusta m. migratorioides*, found it to be a satisfactory one, the ratio E/D (ratio of length of elytron to the maximum vertical diameter of the eye) being over 15 in the males and about 16 in the females of the *gregaria* phase, as against 13 in the males and 14·5 in the

**Footnote* :—These have since been determined to be *Patanga japanica* through the kindness of Mr. D.K. McE. Kevan, Nottingham.

females of *solitaria*. The writer had opportunities, recently, of measuring the E/D ratios of several specimens of the desert locust and found them satisfactory for this species also, but very great accuracy in the measurement of the diameter of the eye is necessary, to ensure that the ratios are correctly evaluated.

Working on the phase value of external characters in *Schistocerca*, Roonwal [1946 a] found the metasternal interspace to be of definite value as a phase character, there being clearly recognizable differences in both the sexes, but did not find [1946 b] the variation in the number of hind-tibial spines to have any phase significance.

Roonwal [1945] has also put up tentative hypotheses in respect of detecting tendencies for swarming in locust populations, on the basis of (1) the relative percentage of 6 and 7 eye-stripes among individuals in locust populations found in any particular area, (2) the relative proportions of the sex-ratios among such populations, and (3) the rise of percentage of six-striped forms above 82 percent. in males and 60 percent. in females. While there is no doubt that these indications in respect of the incipiency of outbreaks are valuable, it should be kept in mind that a rise in the percentage of *gregaria* forms as well as of 6-striped ones is generally due to different degrees of crowded breeding in the immediate past, and that, unless conditions favourable for crowded breeding follow, there can be no surety that such populations would be up-graded into the regular *gregaria* swarms.

In another paper, Roonwal [1947] has given an excellent description of the structure of the compound eyes of the desert locust and the variations found in them, and his remarks on the role of vision in striped and unstriped eyes and its effect on the behaviour of *gregaria* and *solitaria* phases are illuminating. His statements in respect of the development of eyestripes, however, call for a few remarks. While accepting the results of the work of Volkonsky [1938] and Mukerji and Batra [1938] as confirming his own finding that 'as a rule a stripe is added with each moult', Roonwal states that he has found important exceptions. According to his observations 'extra-moulting *does not necessarily* lead to the addition of a stripe'. He differentiates between cases of moults where a stripe may be added, termed by him 'stripe-positive' and those in which none is added—'stripe-neutral'. He also found in two cases that six-striped forms had undergone extra-moulting without getting an additional stripe and that in 13 cases, 7-striped forms had developed without undergoing extra moults. According to Roonwal, two stripes had in these instances, been added instead of one at the second moult. (The production of two stripes at one time appears, however, from the very nature of stripe development, to be rather very extra-ordinary.) He has also adduced indirect evidence to support his contention, based on the proportion of 6 and 7 striped forms and the percentage of sex-ratios among locust populations found in the swarm-free period, which is very ingenious but unconvincing. Since Volkonsky, Mukerji and Batra categorically claim 'an absolute moult-stripe correlation', only further work can settle the question and it is to be hoped that other workers would take up the problem and that, in the words of Roonwal, "a detailed study of breeding would show important exceptions to such *allegedly absolute correlation*".

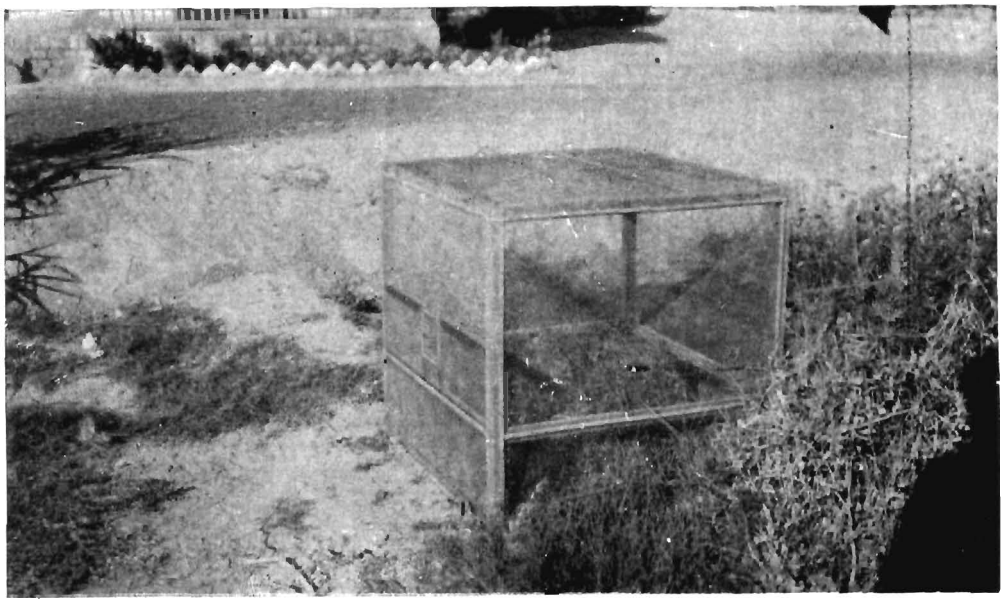
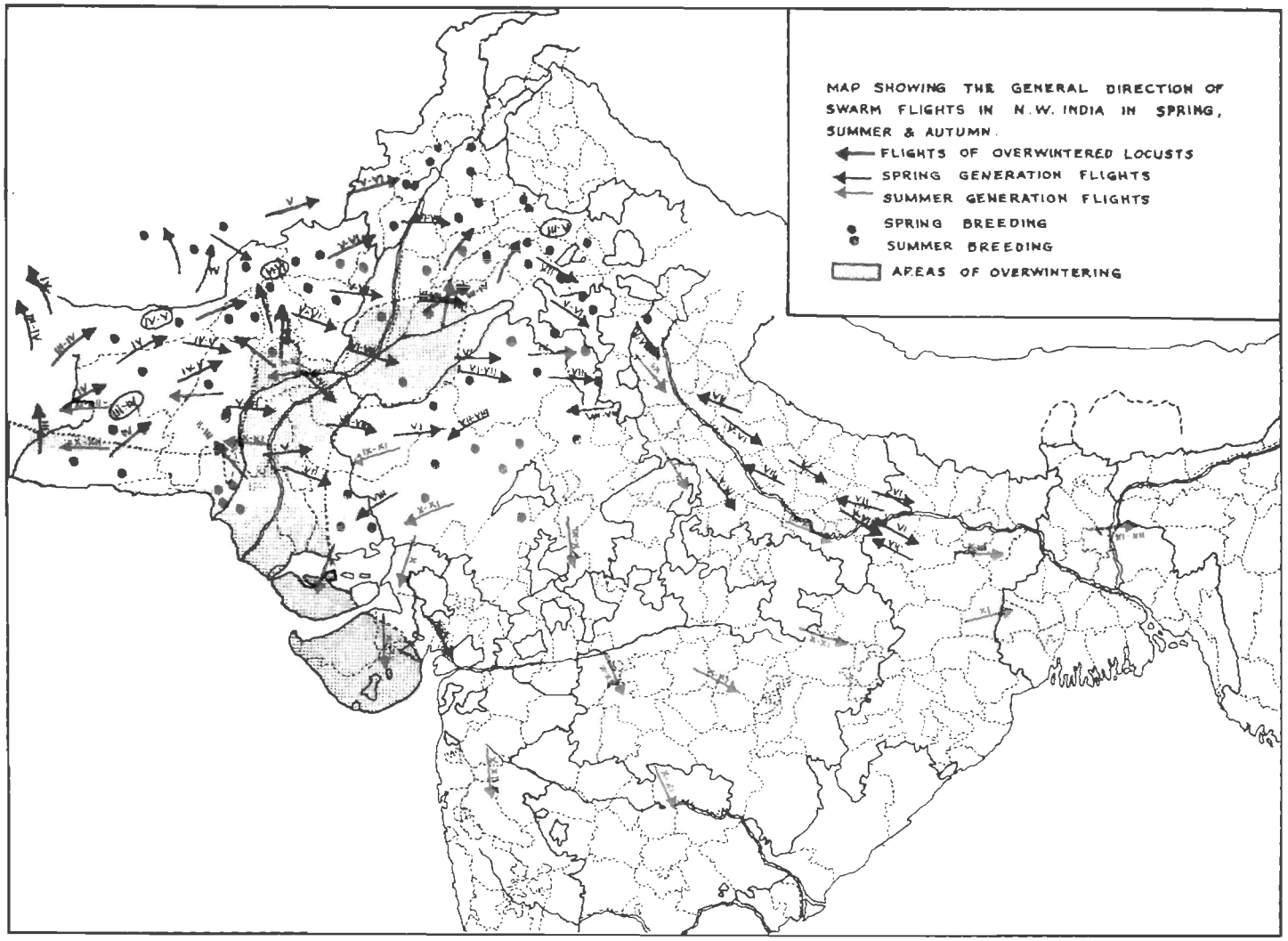


Plate 32.—*Wire-gauze cages—3 ft. × 3 ft. × 3 ft.*—With open bottom, used for covering plants growing on the ground.


MAP SHOWING THE GENERAL DIRECTION OF SWARM FLIGHTS IN N.W. INDIA IN SPRING, SUMMER & AUTUMN.
FLIGHTS OF OVERWINTERED LOCUSTS
SPRING GENERATION FLIGHTS
SUMMER GENERATION FLIGHTS
SPRING BREEDING
SUMMER BREEDING
AREAS OF OVERWINTERING

SECTION V.—GENERAL CONCLUSIONS

CHAPTER—I

AN ANALYSIS OF SURVEY DATA FOR 1931—1939

IN the following chapters, it is proposed to make a general review of the data recorded in the previous sections and to indicate some general conclusions that may be drawn in the light of the knowledge obtained in the course of recent years on the locust problem in India. An analysis of the mass of information recorded in the course of locust surveys, carried out in the areas of Sind, Baluchistan, western Rajputana and southern Punjab under the locust research scheme of the Imperial Council of Agricultural Research, will first be made and the conclusions they may lead to will be summarized. The second chapter will be devoted to a statement of all the evidence that has been gathered in the course of survey work on the normal seasonal occurrence of long distance migration among the solitary individuals of the desert locust in the Indian area. The information gathered in regard to the location of outbreak centres within Indian limits will next be recorded and discussed in connection with the question of the control of incipient swarms for preventing new outbreaks of the locust. The final chapter will be devoted to general considerations of the locust problem in the light of the progress made in locust research in other parts of the world.

An Analysis of the results of Locust Surveys carried out during the period 1931—1939

In Section III, a fairly detailed account of the various field observations made on locust developments in the Indian area of habitat of the *solitary phase* of the desert locust, correlated as far as possible with meteorological data, has been given. All definite reactions on the part of the solitary phase locusts to particular weather conditions, noticed by the staff, have been recorded. In this chapter an analysis of the observations recorded for the different years is proposed to be made for drawing general inferences on the nature of movements and activities of locusts in reaction to weather conditions, as these will be of considerable help to the desert scouts in making an estimate of the state of locust developments, from the point of view of the origination of locust outbreaks.

A comparative examination of the annual cycle of events connected with the development of locusts of the solitary phase shows that there is, on the whole, a striking uniformity in respect of the succession of occurrences connected with the change of the seasons, though corresponding with fluctuations of seasonal conditions in particular years, much variation in the degree of development of locusts is also observable.

Stated briefly, the following would appear to be the general sequence of developments during the different seasons of the year. (1) During the winter months of December, January and February, locusts are generally met with, in an over-wintering condition, mostly in the coastal areas of Mekran and Lasbela, but sometimes also in parts of the Sind-Rajputana desert. (2) With the fall of winter rain in the Mekran rek areas, locusts become mature and breeding usually follows in the spring months. (3) Between February and May, a migration of the old over-wintered adults may take place from the coast into the upland valleys of Mekran and Baluchistan, and may bring about light or heavy breeding in the interior valleys according as the rainfall is light or heavy. Heavy breeding may lead to incipient swarming. (4) In May, June and July, the interior of

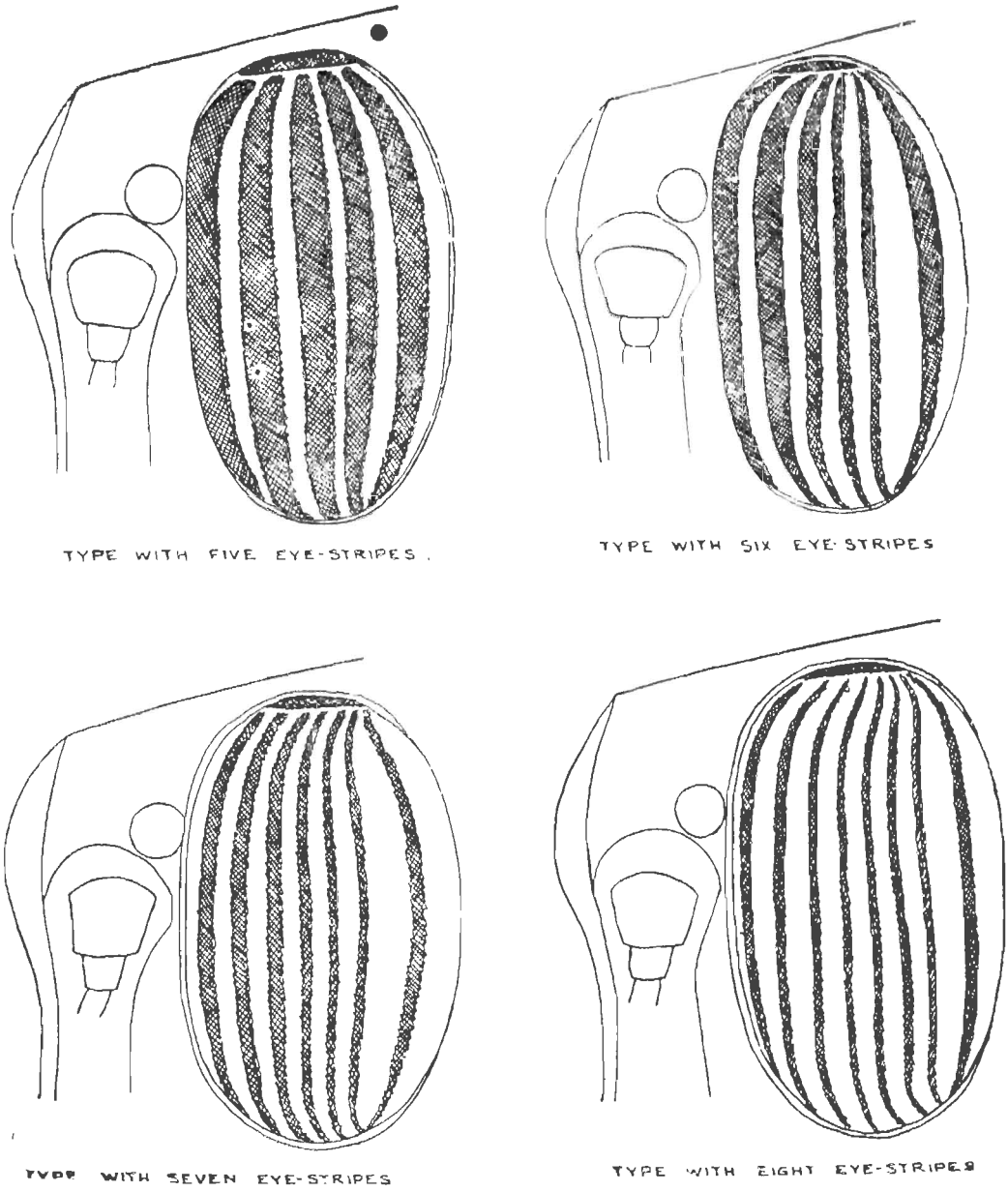
Mekran becomes an area of summer drought, and at this time, the generation of locusts produced here would appear to leave the area and get carried by the prevailing winds eastwards into Sind and Rajputana. At intervals, however, strong and intensely hot north-westerly winds (*Gorich*) may develop in Mekran, during the prevalence of which locusts would appear to be carried southwards into the coastal areas. Ultimately, however, even these migrate eastwards from the coastal areas by the middle of August. (5) In the Kachhi plain and in the neighbouring mountain valleys such as Bolan and Harnai, breeding may occur between March and May, in case good rainfall is received in February and March. (6) In the Sind-Rajputana desert areas, few locusts are usually to be seen during March and April, but from May onwards they are met with in increasingly large numbers, being doubtless derived from the spring brood areas in Mekran and Kachhi. (7) When good monsoon rains are received in June and July, eggs are laid almost immediately, and adults of the new generation begin to appear by the end of July or in August. If there is further good rainfall in August or September, further egg-laying by the old generation may occur, and in addition, a good many of the adults of the new brood may also become sexually mature and lay eggs and thus start the second generation of the monsoon season, the adults of which would be found appearing in October-November. (8) The monsoon usually withdraws from north-west India during September, and a period of dry hot weather generally intervenes before winter conditions set in. During this dry spell, locusts would appear to leave the desert areas, being carried towards the west or south-west by the north-easterly winds that prevail at this time. (9) If there is no late breeding, few locusts remain in the Rajputana desert by the end of October, but if a late or a second brood develops, the adults appearing during late October or in November do not feel any urge to migrate from the area in view of the mild weather then prevalent, and very often pass the winter in the desert. (10) The over-wintered locusts may breed lightly in February-March, if there are good winter rains, but they generally leave the area migrating westwards in March on account of the rise of temperatures in the desert.

In analysing the course of events observed during the period of the present investigation—1931 to 1939, it is seen that while the sequence of events has been practically the same, the degree of development under each event has been subject to a great deal of variation. The causes of such variation will now be examined and as far as possible their relation with the changes in the weather conditions will be studied.

1. Over-wintering

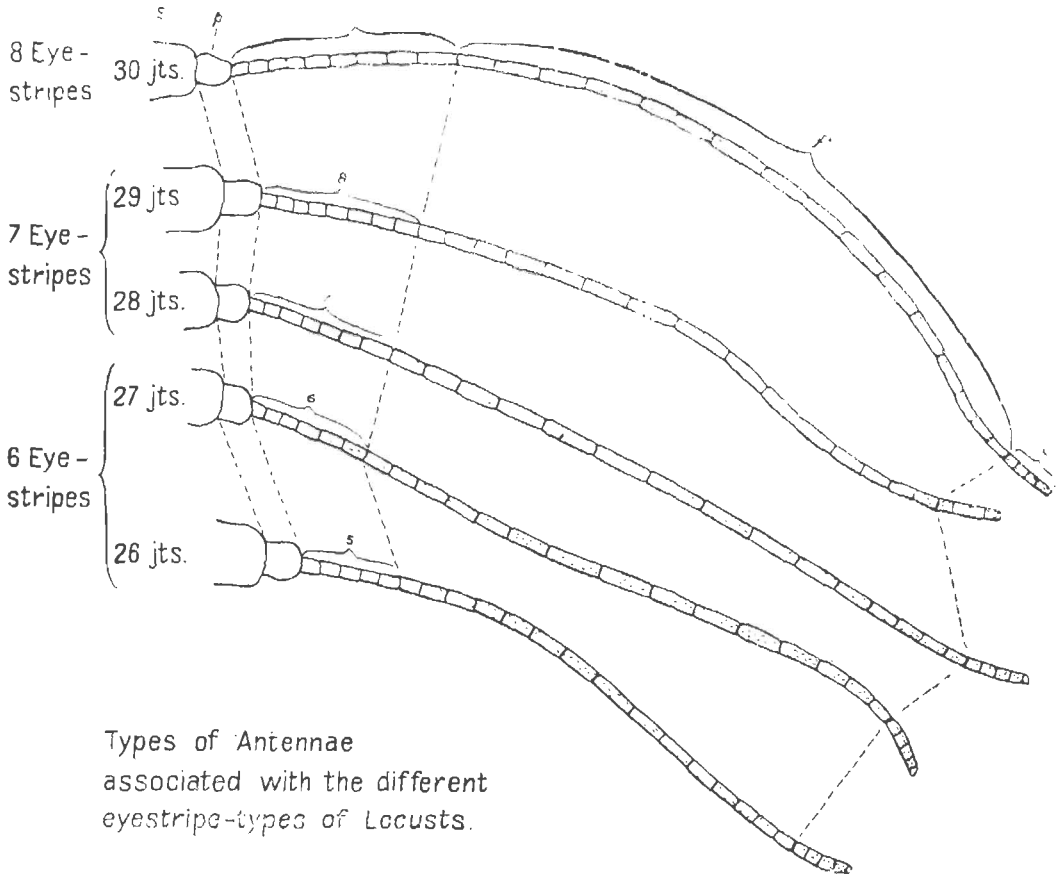
In regard to winters of 1930-31 and 1931-32 only scanty information is available. Moreover, the prevalence of swarms during these years renders the situation rather complicated. From Table XVII, it is obvious that considerable over-wintering occurred in parts of the Rajputana desert, and in the Lasbela and Mekran areas during the winters of 1933-34, 1935-36, 1936-37 and 1937-38. It is seen also that summer breeding in the Sind-Rajputana area in the summer preceding had been fairly heavy and prolonged, and late breeding had occurred. On the other hand, during the winter of 1932-33, 1934-35, 1938-39 there was no over-wintering in the Rajputana desert areas, very little in the Lasbela area and light in the Mekran reks. In 1932, there was no rainfall after 15 August, and in 1934, there was none in September in the Rajputana area, while in 1938 the monsoon was very defective in most parts of Sind and Rajputana, so that breeding was quite restricted in all these three years, and late breeding was practically absent. It is obvious from the table given that the occurrence of over-wintering is dependent on late breeding in the desert

Text Figure 18]



18 Four figures showing eye-stripe types: (1) with 5 stripes, (2) with 6 stripes; (3) with 7 stripes & (4) with 8 stripes

Text Figure 19]



Types of Antennae found in forms with different types of eye-stripes. *s.* scape ; *p.* pedicel ; *f.* funicle ; *c.* club or flagellar tip. 5-9 : no. of joints in proxinal region of growth,

TABLE XVII

Over-wintering of adult locusts correlated with summer breeding

Nature of summer breeding in the Desert areas	Year	*Over-wintering of adult locusts*		
		Sind-Rajputana Area	Lasbela area	Mekran area
Summer 1930 No information for *Solitaria*; Swarm breeding ceased by end of August; *no late brood.*	Winter 1930-31	No over-wintering swarms; Scattered locust individuals found in Bahawalpur, Lasbela and Mekran areas in April-May, 1931.		
Summer 1931 Swarm breeding in Ajmer, Jodhpur and Bikaner areas till beginning of October:	Winter 1931-32	No information	Small numbers found	Scattered locusts all over.
Summer 1932 No rain after 15th August. *No late breeding.*	Winter 1932-33.	Few locusts	Small numbers	Fair numbers.
Summer 1933 Good rainfall June-September *Heavy late breeding.*	Winter 1933-34	Fair numbers	Heavy population	High population.
Summer 1934 No rain in September. *Only one brood.*	Winter 1934-35	No locusts	No locusts	Light population.
Summer 1935 Light rain August-September. *Late breeding only in Thar area.*	Winter 1935-36	Over-wintering in Chachro area.	Good numbers	Large population.
Summer 1936 Heavy rain in August. *Heavy late breeding in the northern desert areas.*	Winter 1936-37	Heavy over-wintering in northern desert areas.	Fair numbers	Fair numbers.
Summer 1937 Good rain in September. *Heavy late breeding in Thar-Mallani* area.	Winter 1937-38	Over-wintering in Chachro areas.	Good numbers	Fair numbers.
Summer 1938 Little rain in August; none in September. *No late brood.*	Winter 1938-39	No locusts	Few locusts	Few locusts.

The early brood would appear to leave the desert areas by September and gradually drift westwards to the Baluchistan areas by October and November, and subsequently pass off beyond the frontiers into the Iran areas. If there is late breeding, flights of the second generation would follow during October and November, but with the advent of winter, these locusts may over-winter either in parts of the desert or in the Lasbela and Mekran areas.

During the cold season of 1937-38, a few hoppers also were found over-wintering along with the adults in the Thar area, but, as a rule, only adult locusts over-winter.

2. Spring Breeding on the Western Reks

The extent and intensity of spring breeding on the western reks of the Mekran coast would appear to be directly commensurate with the amount of winter rainfall received (Table XVIII). Fairly heavy spring breeding was noticed on all the reks—Gwadar, Pasni, Ormara and Hingol, in 1933, 1935 and 1939 as a result of heavy winter-spring rainfall, while during the spring of 1932, 1934 and 1937, there was an absolute absence of breeding in consequence of an almost total failure of winter-spring rainfall. In 1931, 1936, and 1938, winter precipitation occurred all over the coast, but was below the average, and the spring breeding was, accordingly, light to moderate in character.

3. Late Spring Breeding in the Interior of Mekran

(a) *Spring migration.* Since June, 1933, regular surveys of the interior of Mekran were carried out throughout the year, as a result of which it was clear that, as a rule, very few locusts were noticeable in the interior of Mekran during the winter months. From March onwards, however, increasingly large numbers were usually met with. From the biometrical characters of the population met with in the interior during the perioc March to May in the years 1935 and 1936, and from the evidence furnished by the presence of *green algae* on locusts collected at this time in 1937 and 1938, it is obvious that they were derived from the coastal population of Mekran. The occurrence of yellow-winged forms carrying *green algae* in Kachhi-Bolan area in 1937 and 1938, and the find of a yellow-winged male with mature *green algae* as far north as Dalbandin on 4 April, 1938 are clear indications of the existence of a general spring migration from the coast towards the interior with the advance of spring.

Predtechensky [1935] noted a similar migration in the spring months in Persia during the years 1927, 1928, 1929, 1930 and 1931 in the case of the swarms of the yellow locust, from the coastal regions of southern Iran, where over-wintering usually occurred, into the uplands of Iran Similar migration of the over-wintered yellow swarms was noticed in Baluchistan in spring during the last cycle. The probable cause of such spring movements may be due to the circumstance that a rise of temperature accompanied by a progressive desiccation of the soil starts much earlier in the southern coastal plains than in the upland valleys to the north. On the coastal areas, the south-west winds from the sea are prevalent in the afternoons in the spring months and presumably carry the locusts—whether as swarms or as individuals—into the upland valleys to the north, which by reason of a more northern latitude and a higher altitude offer suitable ecological conditions for locust breeding till late in the season.

(b) *Development of outbreak centres.* As a result of good showers of rain in spring in the interior in 1935, concentrated breeding was noticed in suitable localities between April and June, leading to the development

TABLE XVIII

Analysis of Winter-Spring Breeding in Mekran Area : 1931 to 1939. also 1926

Year	Winter Rainfall			Density of over-wintered population	Nature of Spring Breeding				Incursion from the hinterland into coast in summer
	General characteristics and months of rainfall	Total rainfall (in inches)			Coastal breeding	Migration from coast into interior	Breeding in hinterland	Outbreak Centres if any	
		at Pasni typical for coast	at Panjgur typical for interior						
1931	Late, but fairly good. (*I, II, III*).	5·71	2·90	In good numbers.	Fair (IV-V)	No information.	Light breeding.	Nil .	Pink swarm appeared at Pasni in July.
1932	Failure of rain on coast and interior.	0·98	1·30	Fairly good numbers.	Nil .	Not noted	Not noted	No information.	Incursion noted on 24th May on reks; continued in June.
1933	Late, but heavy (*II & IV*).	12·09	5·30	Fair numbers.	Fairly heavy.	Quite probable.	Good breeding in Kolwa & Panjgur.	Possibly Kolwa & Panjgur.	No definite incursion, but increase of population in VI and VII at Pasni.
1934	Complete failure .	0·66	0·69	Fairly heavy.	Nil. .	Light migration in March.	Nil .	Nil .	Light rise of population in May at Pasni.
1935	Early and heavy (*XII, I and II*).	11·44	8·60	Fair numbers.	Extensive breeding (*II—V*)	Fairly clear biometrical evidence	Fairly heavy (*III—VII*)	Three centres noted.	Heavy incursion in July-August.
1936	Moderate . (*I, II, III*).	3·25	3·48	Good numbers.	Moderate (*III—V*)	Fair evidence.	Light breeding. (*III—VI*)	Kolwa (*III—IV*)	Light incursion in May-June.

TABLE XVIII—(*contd*)

Analysis of Winter-Spring Breeding in Mekran Area : 1931 to 1939. also 1926—cantd.

Year	Winter Rainfall			Density of over-wintered population	Nature of Spring Breeding				Incursion from the hinterland into coast in summer
	General characteristics and months of rainfall	Total rainfall at Pasni typical for coast inches	Total rainfall at Panjgur typical for interior inches		Coastal breeding	Migration from coast into interior	Breeding in hinterland	Outbreak centres if any	
1937	Failure on the coast ; moderate in interior.	1·23	2·87	Good numbers.	Nil.	Good evidence.	Fairly good (*IV—VII*).	Centres at Sheh Lakhra ; Kachhi-Bolan. Light breeding in Panjgur area.	Light migration from interior into coast in June.
1938	Moderate on coast ; poor in interior.	3·71	1·59	Good numbers.	Light (*III—V*)	Good evidence.	Light (*III-VI*)	Good breeding in Kulanch.	Light incursion in June.
1939	Prolonged and fairly heavy (*XII, I, II, III & IV*).	10·43	5·16	Small numbers.	Fairly good	No information.	Fairly good.	G od breeding in Kulanch, Kech and Kolwa.	Light incursion in July.
1926	Heavy rainfall in January on the coast and interior ; Good falls in the interior in March and May.	8·06 (7·54 January)	5·78 (*I*—3·69 *III*—*1·38*)	*Not known*	Good	Not known but highly probable	Heavy breeding.	Centres *in Kulanch.* Probably also Kech and Kolwa.	Incursion probably reached Kachhi in June-July ; and Lasbela and Rajputana in July-August.

of incipient swarms in the Kech, Panjgur and south Kharan areas, which represented to a large extent the second spring generation derived from parents produced on the coast.

In 1936 an outbreak centre was found to have developed in the Kolwa area in March-April, brought about by the concentration of over-wintered individuals of the old generation. Fairly good breeding also occurred in Kulanch at about the same time. In addition, light breeding representing the second generation of spring was noted in June at Nigar-Kan-Daf in the Panjgur area.

In 1937, desiccation set in very early on the coastal areas owing to the failure of rain, which would appear to have caused the migration of locusts into the inland valleys of Mekran and Upper Baluchistan. Consequently, an outbreak centre developed at Sheh Lakhra in the Porali valley of Lasbela in the spring months. Heavy breeding, also occurred on the Kachhi Plain and in the Bolan valley in April, May and June, and there is little doubt that the infestation was started by locusts derived from the Lasbela and Sind-Rajputana areas, where over-wintering had been noticed. There was, moreover, a fair amount of breeding in the Panjgur area, especially in the Gar-Parom section in June and July, representing the second generation of the season.

In 1938, there was little breeding in the interior in view of the defective rainfall, except in the Kulanch area.

In 1939, heavy winter rainfall occurred both on the coast and in the interior of Mekran, and good breeding was noticed in the Kulanch, Kech and Kolwa areas between March and June, and it is possible that the breeding might have led to the formation of outbreak centres if the initial locust population on the Mekran coast in the winter of 1938-39 had been denser. Heavy breeding would appear to have occurred in the Kachhi-Bolan areas also in the spring of 1939.

In 1926, the year of the commencement of the last great cycle, very heavy rainfall occurred in January both on the coast and interior of Mekran and led to heavy breeding on the coast. Subsequently, there was good rainfall in the interior in March and later on in May, which presumably induced widespread formation of outbreak centres in Kulanch in May, and there is reason to believe that some breeding occurred at the same time also in the Kech and Kolwa valleys.

4. Locust Movements in Summer

The climate of the western parts of Baluchistan resembles that of the regions further west, such as Iran, Iraq and Arabia. It is of the Mediterranean type with rainfall mostly in winter and spring and with a pronounced summer drought. Rains practically cease in March or April, and by the end of April or the beginning of May, there is a distinct rise of temperature accompanied by a fall of humidity. In years when winter rains fail conditions of desiccation set in very early, sometimes even in April, whereas in years of more than average rainfall, the seasonal changes manifest themselves late, by the middle or end of May.

These changes generally take place gradually with the advance of the season, but abrupt rises also occur fairly frequently either as the result of a heat wave or in the wake of one of the western disturbances. High temperatures are generally accompanied by dry hot winds from the north or north-west, and may persist for a week or ten days, after which milder weather may prevail for a longer or shorter interval, till another heat

wave develops. In the Mekran area, south-west winds from the coast generally prevail in the afternoons during these intervals, while north-west winds (*Gorich*) blow while the heat wave lasts.

With a general rise of atmospheric maximum temperatures to over 100°F (the soil surface temperatures being naturally much higher), and a corresponding fall of humidity, which usually take place by the beginning of May, locusts would seem to feel an urge to leave the area, and while the south-west winds prevail, move up through the valleys of southern Baluchistan into Kachhi and west Sind, and thence into south-west Punjab and Rajputana. On the other hand, when the north-west winds are active, locusts find their way into the coastal areas from the interior. Ultimately, however, even those reaching the coast gravitate into the desert areas *via* Lasbela and Sind.

(a) *Locust incursions.* In 1932, a definite incursion of locusts mostly of the *gregaria* type—occurred on 24 May on the Mekran reks, and was associated with the prevalence of dust storms from the north that had developed during the heat wave of 22 and 23 May in Upper Baluchistan. In July 1935, a similar incursion of locusts but of much greater magnitude likewise connected with the development of conditions of high saturation deficiency in the interior, was experienced on the coastal areas of Mekran and Lasbela, and in the Thar area of Sind, during the second week of the month. Similar, but much lighter, incursions were noted in the Pasni area in May 1936, in June 1937 and June 1938, and in all cases a sudden rise of temperature in the interior was found to be involved.

(b) *Summer migration.* In the Sind-Rajputana region, regular observations were begun only from June 1933, and during the period 1933 to 1939, few locusts were noticed in the desert areas during the winter of 1934-35, and 1938-39 (Table XIX). In fact, in these cases no locusts were observable till May-June. In the case of the other years, over-wintering of locusts was observed during the winters of 1935-36 & 1937-38 in the Thar area, and in 1936-37 in the East Jaisalmer-Bikaner area, but even in these years most of the locusts disappeared by the end of March, none being observable during April. In any case, specimens of a recently developed generation were always found appearing by May or June in most parts of the Sind Rajputana desert, and as these were not locally developed ones, it is fairly evident that they represented migrants from the western areas of winter-spring breeding.

With the development of high temperatures in the western areas, locusts would appear to quit them in May-June and to migrate with the south-westerly winds generally prevalent at this period (except during the prevalence of a hot wave) towards the north-east or east into Sind, S.W. Punjab and Rajputana. As a rule, most of the early migrants reach the northern parts of the desert, the migration being directed to the south only when north-westerly winds prevail accompanied by rise of temperatures in Baluchistan.

In the Thar-Mallani area, locusts may arrive directly from the western areas, but may more often be conveyed there from the north or north-east by winds connected with the passage of a monsoon depression. In 1938, no locusts were observed around Chachro till 22 July, when with the fall of heavy rain due to a depression, fairly good numbers were noticed on subsequent days. In fact, as already mentioned earlier, according to reports of local people swarms usually appear in the Thar area from the east or north-east during years of locust infestation.

In 1937, when heavy spring breeding occurred in the Kachhi and Bolan areas, individuals of a new generation began to appear in the Jaisalmer-Bikaner areas as early as the middle of May. As owing to lack of rainfall there was no spring breeding in the Mekran coastal areas nor any extensive multiplication in the hinterland, most of the migrants found in May and June had doubtless originated from the Kachhi-Bolan areas or from the Sheh Lakhra area in Lasbela. On the other hand, in 1938, when there was no spring breeding in the Kachhi area and but little in Bolan, few locusts were met with in the Jaisalmer-Bikaner areas till the end of June, but in 1939, when spring breeding occurred in Kachhi-Bolan, the earliest immigrants of the year (presumably from Kachhi) were noticed early in June in the Jaisalmer-Bikaner area. As, on the other hand, the origin of the spring infestation in Kachhi-Bolan in 1937 was traceable in great part to over-wintered locusts from the Jaisalmer-Bikaner areas, there is probably some kind of linkage between the two areas in regard to locust breeding.

5. Summer Breeding

(a) *Breeding in Sind-Rajputana area.* The migrants begin to appear in the Sind-Rajputana areas generally by the end of May or the beginning of June and the immigration may continue up to the middle of August. By the middle of June, a fair proportion of them is sexually mature and in case the monsoon rains commence by the latter half of June, as they did in 1933, 1934 and 1936, oviposition takes place almost immediately. In fact, in 1938, an inch of rainfall was received at Barmer on 31 May, and hoppers were noticed there by the end of June.

July is generally a month of good rainfall, in which egg-laying is in progress throughout the month and the first hoppers may always be expected by the middle of the month. The June-July batch forms the first monsoon brood, the new adults of which usually make their appearance by the middle of August. Should there be good rainfall also in August, the migrant locusts may be able to lay a second, and sometimes even a third batch of eggs in some part or other of the desert, so that hoppers of the first generation may be found even up to the middle of September and may continue to transform into adults even up to the end of September.

Generally, however, a break of 2 to 5 weeks' duration in the monsoon rainfall occurs either in part of July, as in 1934 and 1938, or in July-August, as in 1935, or in August-September, as in 1932, 1937 and 1938 (*vide* Table XIX). Such considerable breaks in the seasonal rainfall have the effect of causing the sand-soil moisture to dry up, and sometimes of accentuating the saturation deficiency of the atmosphere, as a result of which locusts find the conditions unsuitable for further egg-laying and usually leave the area in quest of other laying grounds.

In certain years, namely 1931, 1933, 1934 and 1936, August proved to be a period of heavy rainfall in many parts of the desert, and gave rise to heavy locust breeding. In 1933 and 1936, fairly good rain was received also in September, thereby causing an extension of breeding into the autumn months.

Field observations have shown that, in case there is sufficient rainfall in August, adults of the new generation appearing at the beginning of August are able to attain sexual maturity by the end of August or the beginning of September, and to lay eggs, so as to bring the second monsoon generation into existence. As very often the last batches of eggs of the old generation may also be laid at the same time, an over-lapping of

generations is bound to occur at this period, though by the end of the breeding season the hopper population may be expected to be made up purely of the second generation.

The production of the late brood—which in effect is mostly composed of the second generation of the monsoon—is a factor of considerable importance in locust epidemiology. The greatest increase in numbers would occur only if one fairly large brood is quickly followed by a second one within the same breeding period. Otherwise, in view of the likelihood of casualties in the course of autumnal migration and over-wintering by reason of adverse weather conditions and attacks by enemies, a considerable decimation in numbers of the new generation is likely to occur before it can breed again in the following spring. In 1926, there was fairly heavy and almost continuous rainfall during July, August and September in the desert areas, especially in the southern parts of the desert—where rainfall was heavy in September. Consequently extensive breeding in July-August was followed in September-October by a second generation mostly in the southern desert, where, favoured by the dynamics of depressions, large numbers of locusts would appear to have been carried by winds from the northern or north-eastern parts of the desert to the southern and south-western areas. Apparently fairly large concentrations were caused to form here, leading to crowded oviposition and the ultimate formation of large swarms. The latter would appear to have spread southwards into Cutch and Kathiawar, north-westwards into southern Punjab and westwards into Sind and Baluchistan, and thus initiated the locust cycle of 1926-1931.

In 1935, on the other hand, good precipation in July was followed by deficient rainfall and partial drought in August and September, so that the fairly good breeding that commenced in the wake of the incursion of considerable numbers of locusts from the west was interrupted by the lack of rainfall in August and there was only a feeble development of the second monsoon generation in September-October.

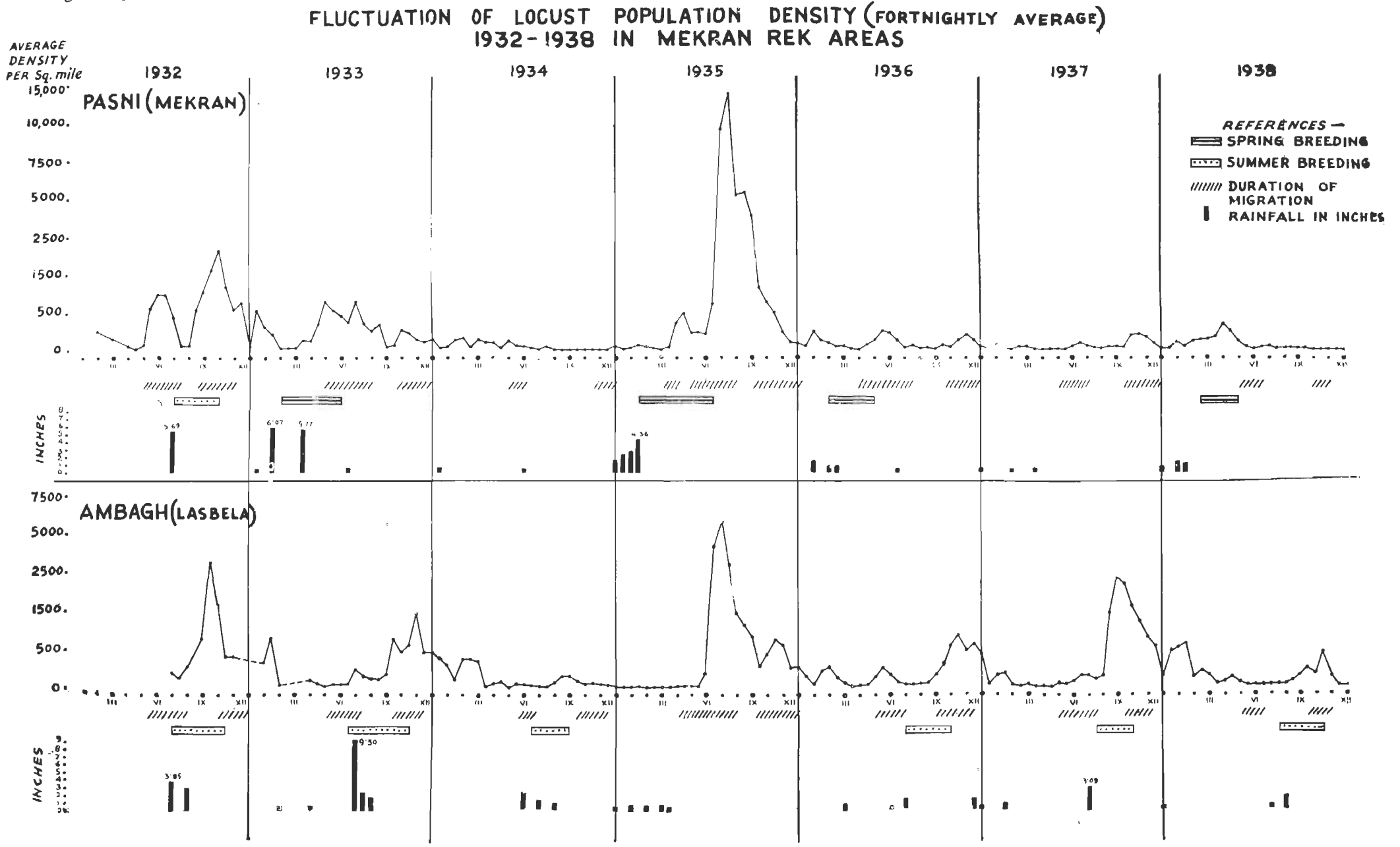
In 1933, when heavy multiplication occurred as a result of heavy rainfall, especially in the northern areas, a few loose swarms had apparently been produced, which were reported from the outskirts of the desert areas near Muttra and in the Bikaner-Bahawalpur areas.

In 1936, a considerably large increase of *solitaria* population was noticed in the Jaisalmer-Bikaner areas in November as a result of late breeding induced by heavy rainfall in August, but apparently as a result of dense vegetation acting as a brake on hopper movements, crowding was prevented, as had been recorded by Kennedy (1939) in the course of his work on the Red Sea Coast.

From the experience gained during the last few years, it is obvious that August and September are rather critical months in respect of locust breeding in the desert areas, as the extent of multiplication during a particular year is entirely dependent on the character of the precipitation received during this period.

(b) *Summer breeding in the Baluchistan areas.* Summer breeding generally occurs in the Lasbela, Kachhi and Mekran areas in years in which the monsoon extends its influence into them. Between 1931 and 1939, there was no summer rainfall in the Lasbela and Mekran areas in 1931, 1935 and 1939 and consequently no summer breeding. On the other hand, in 1932, when a depression carried heavy rainfall into the Lasbela area and into the Mekran coast and interior during July, extensive breeding was observed all over these areas in July-August-September. In 1933, also heavy rainfall occurred in July in the Lasbela

Text Figure 20]



Text Figure 21]

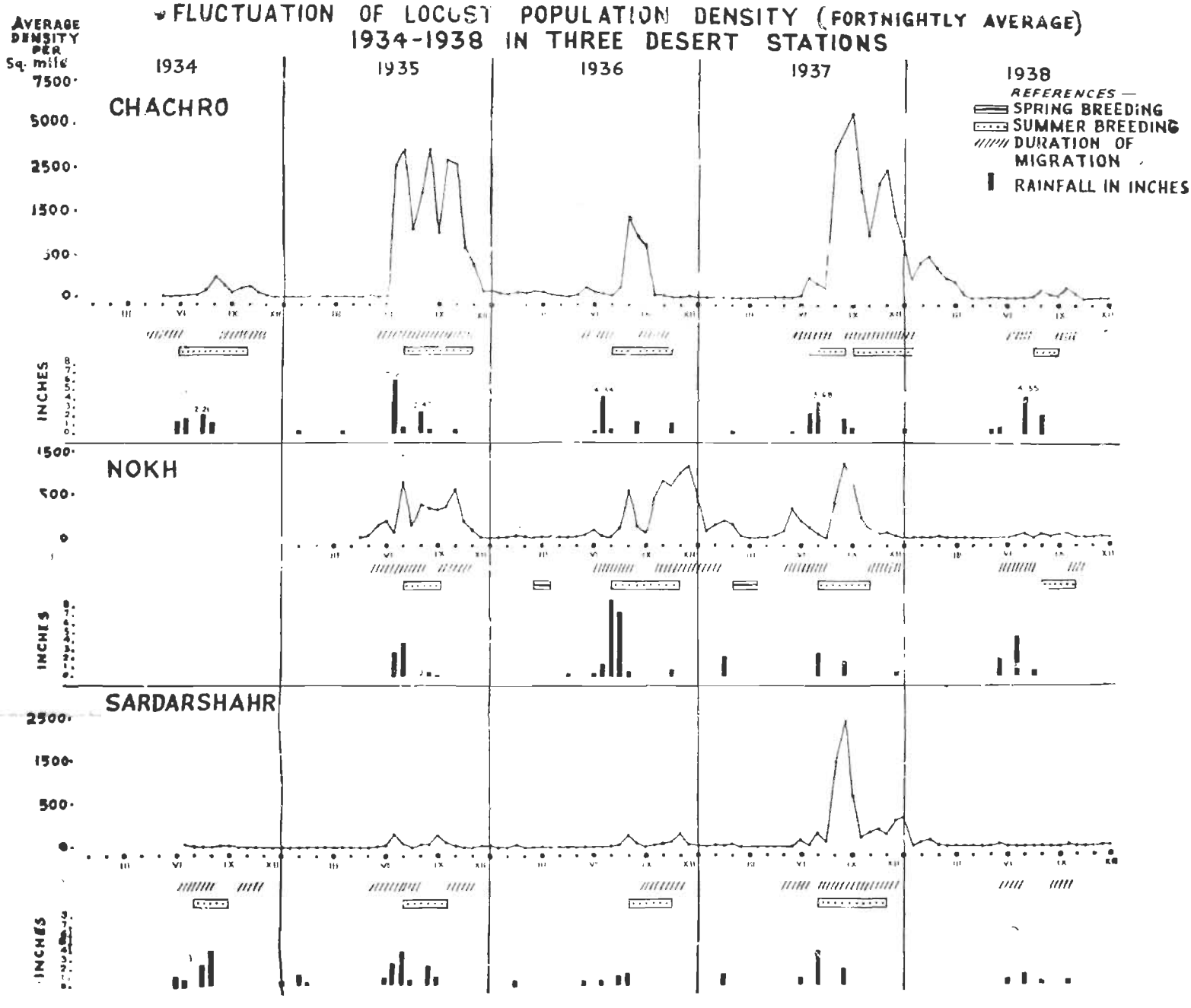


TABLE XIX

Analysis of Date on Summer Breeding in Monsoon Areas—1931 to 1939, and also 1926

Year	General character of rainfall	Particulars of summer rainfall (Monsoon)				Breeding data.							
		Monsoon rainfall data in inches				Break in monsoon if any	Date of withdrawal of monsoon	Arrival of migrantes	Sind-Rajputana		Lasbela	Autumn migration	Over-Wintering
		Northern Desert Type Bikaner		Southern Desert Type Barmer				Earliest Date	First generation	Second generation			
		May to July	Aug. to Sept.	May to July	Aug. to Sept.								
1931	Heavy rain in August in Marwar.	5·86	5·22	2·08	22·20	Little rain in Sept.	10th Sept.	No information.	Swarm breeding continued into October.		No rain and no breeding.	Migration in Oct. and Nov.	No date.
1932	Good rain in July and Aug. first half.	5·29	2·78	8·06	2·93	No rain after 15 August.	25th Sept.	15th June at Khairpur.	Only one generation.	No late brood.	Good breeding.	Early autumn migration.	Nil.
1933	Good and continued rainfall June to September.	4·55	11·87	6·54	5·65	No break.	27th Sept.	Middle of June in West Sind.	Extensive breeding vi-ix.	Fairly extensive second breeding Oct.-Nov.	Fairly heay breeding.	Swarms reported Oct.-Nov. Migration from Oct.	Large over-wintering population
1934	Good rain end of June to 7-vii. Heavy rain in August. No rain in September.	4·12	12·06	3·59	6·94	Break of 3 weeks in July. No rain in September.	15th Sept.	First locust at Chachro on 19th May.	Only one generation.	No second brood.	Light breeding.	Migration in Sept. Oct.	Nil.
1935	Good rain in July; light in August; moderate in September.	5·36	6·00	6·24	3·46	Break from 23-vii to end of Aug.	20th Sept.	First locust on 17-v at Chachro. Incursion in vii.	One main generation	Second brood very light	No rain & no breeding.	Migration in Sept. Oct. & Nov.	Light over-wintering in Thar area.
1936	Rains began in June, heavy in August in north: light in September.	4·30	13·88	3·96	2·86	Break from 2nd week July to 2nd week of August.	19th Sept.	15-v at Chachro.	1st brood all over desert.	A heavy second brood in Northern desert.	Moderate breeding	Migration active in September October.	Over wintering in northern desert.

TABLE XIX—*contd.*

Analysis of Data on Summer Breeding in Monsoon Areas—1931 to 1939, *and also* 1926—contd.

Year	General character of rainfall	Particulars of summer rainfall (Monsoon)				Breeding data							
		Monsoon rainfall data in inches				Break in Monsoon, if any	Date of withdrawal of monsoon	Arrival of migrants	Sind-Rajputana		Lasbela	Autumn migration	Over-wintering
		Northern Desert		Southern Desert				Earliest Date	First generation	Second generation			
		Type Bikaner		Type Barmer									
		May to July	Aug. to Sept.	May to July	Aug. to Sept.								
1937	VI-rain in east Bikaner. VII-general rain; VIII—no rain-IX—rain in south and north-east.	8·86	0·34	7·70	1·51	Long break 1st August up to 8th September.	17th Sept.	Nokh-15-v. from Kachhi area ; Jun Chachro.	First brood fairly heavy all over.	2nd brood moderate found in South &. North-east.	Moderate breeding.	Nilyration September and October.	Over wintering in Thar and Mallani
1938	Fair rain in June-July ; light in Aug ; nil in Sept.	2·01	2·60	4·32	0·53	1 Fortnight of July and August dry September no rain.	2nd week Sept.	14-vi Sardarshahr.	Only one generation.	Second brood represented by a few hoppers.	Fairly good breeding.	Migration from middle of October	*Nil.*
1939	Light rain from June to Aug. in Northern areas.	1·00	1·45	0·09	5·75 (5·32 in Aug.)	*North*: deficient rain *South*: dry till Aug. middle Sept. dry.	1st week Sept.	15-vi Nokh: from Kachhi ?	One generation in North. Little breeding in south.	Light II generation in North.	No rain no breeding.	Migration Sept. October.	*Nil.*
1926	Rain in May Good rain all over desert in July-Aug. Heavy rain n southern desert in September.	5·76	5·51	4·62	12·52	1926 *No break.*	Last week September	End of June in Kachhi.	First generation all over desert—viii—ix.	Second generation heavy mostly in southern desert.	Heavy breeding in Oct. Nov.	Sept. —Oct. Nov.	Heavy over winte ring.

areas, but in Mekran the rains were comparatively light in the interior (Kolwa, Kech and Panjgur) and very light along the coast. Heavy breeding was observed in the Lasbela area between August and October, but in Mekran there was only light breeding in the interior, and none on the coast. In other years, varying amount of rainfall was associated in Lasbela with proportionately varying amount of breeding. In Mekran, however, appreciable breeding was noticed only in 1937 and 1938 in Kolwa and Panjgur in summer.

6. Locust Movements induced by Dust-storms or Thunder-storms

In the course of intensive observations made in the Sind-Rajputana area between 1934 and 1938, it was often noticed that, soon after rainfall, locusts were found present in localities where they had not been seen previously. It was at first supposed that the presence of locusts was due to the active attraction exercised by heavy precipitation, but observations made in the course of survey work made it clear that in most cases they are brought into the area by the storms that usher in the rain. On 23 August 1937, large groups of solitary locusts—which were sufficiently numerous to be mistaken for a loose swarm—were reported to have been seen flying with the wind over the town of Sardarshahr at dusk associated with the occurrence of a thunderstorm. In this case, it is surmised that these groups had come from the north-east from Reni, where large numbers of the new brood were known to have been present, and that the latter had, in view of the unusual drought then prevalent, been excited into activity by the cool, moist winds accompanying the thunderstorm and allowed themselves to be carried by the storm into new areas. A similar case was observed in the Kolwa area in Mekran in July 1937, when a fieldman found fairly large numbers of locusts after rainstorms, though none had been seen earlier. In a third case, few locusts were seen in the Nokh area during the first week of August, 1936, but subsequent to the abnormally heavy precipitation experienced during the second week (12th to 16th), large numbers of them were met with in the same area. Apparently they had been carried into the area by the cyclonic movements of the storms accompanying the passage of the depression. Further instances of this kind were noted in July 1938, when the earliest appearance of locusts during the summer synchronized with the first heavy monsoon shower at Chachro as well as at Nokh.

In this connection, certain observations (as yet unpublished) which had been made by Khan Bahadur M. Afzal Husain and his colleagues (Dr Taskhir Ahmed and others) at Lyallpur in August 1931, on the behaviour of caged locusts (and which came to the knowledge of the writer sometime ago), are of particular interest. A large number of locusts, captured from swarms, had been confined in a large wire-gauze cage in the open for life-history work, and in the course of daily observations, locusts were found on two occasions fluttering about in a state of great excitation and dashing against the wire-gauze sides a short time prior to the approach of a dust-storm. It would look as if, in nature, locusts may similarly respond to changes in the atmospheric temperature, humidity and pressure associated with the approach of rainstorms, rise into the air to meet the winds of their own accord, and thus get conveyed by them to likely areas of rainfall (*vide* p. 278 Sect. IV. Ch. II).

In view, therefore, of the possibility of locusts being carried into new areas by storms and of the likelihood of their getting concentrated in localities of good rainfall, the occurrence of thunderstorms and the passage of depressions in summer are of special significance in the development of outbreak centres in the desert areas.

7. Autumn Migration

With the withdrawal of the monsoon current from north-west India during September, the desert becomes an area of drought accompanied by high temperatures. In years of high precipitation during August-September, as in 1931 and 1933, conditions of drought appear considerably late in the season, about the middle of October. On the other hand, in years in which rainfall in August-September is defective, as in 1932, 1934 and 1935, conditions of drought develop fairly early in September, and in 1937, a long break in the monsoon brought about an unusually early drought, in August. During the monsoon months, the maximum temperatures in the desert rarely reach 98°F., whereas they may rise as high as 107°F. during periods of drought developing after the cessation of the monsoon current. The adult locust of the *non-migratory* type is a creature that may generally be found basking in the sun on the surface of sandy soils while the temperatures are moderate. When soil-surface temperatures rise above 40°C., however, they are noticed to seek shade. It has been found that atmospheric humidity is distinctly lower at the soil-surface, especially, during day-time when it is heated by solar radiation, than at the height of the screen, (as shown in the ecological chapter), and the degree of saturation deficiency at soil-surface is specially high when there is little soil moisture. Such conditions may be expected to result in the loss of body-water, and the insect would therefore appear to leave the area by taking flight.

Locusts generally leave the Sind-Rajputana desert area in September-October, and as north-easterly or easterly winds are usually prevalent at this period, the great bulk of them would appear to fly towards Sind and Baluchistan. In one carefully observed instance in September 1936 at Chachro, a dust-storm that appeared from a north-eastern direction on the afternoon of 25 September caried off most of the locusts in that area, with the result that few were to be seen thereafter (*vide* Sect. III 1936). As by the end of the month the population at Ambagh was found to show a sudden rise, it is surmised that a migration in a western direction had taken place. Similarly, in September, 1937, the greater part of a fairly high locust population found in the neighbourhood of Chachro was noticed to have been swept away by a depression that passed westwards over that area on 10 September. More usually, emigration from an area is gradual any may be spread over a large number of days so long as conditions of drought last. Much of the autumn migration takes place generally during October, but it may continue up to the middle of November.

In general, however, the heat abates by November, and a slight rise of humidity also occurs, so that locusts do not find the same urge to leave the area as in September-October. When there is late breeding most of the adults that are produced by the close of October or during November do not appear to show any indications of leaving the area, and the great majority of them apparently pass the winter in the desert areas, though, a certain proportion may, and do, migrate in the course of the winter season during the short spells of comparatively warm weather that sometimes develop there. Over-wintering was observed in the desert during the winters of 1933-34, 1936-37 and 1937-38, all which were associated with late rainfall and late breeding.

8. Observations on the Progress of Solitaria Migration

In the autumn of 1937, periodical observations were made at several points in the semi-desert area stretching between the banks of the Indus and the Hab rivers, in an attempt to get infromation in regard to the progress of migration. It was found that locusts were noticeable mostly

on the sandy beds of various dry water-courses that drain the semi-desert country. It was also observed that, while locusts were met with during October and November, they were not seen in December, indicating the cessation of migration in winter. Small numbers were found again at the end of January 1938 and, slightly larger numbers in April 1938, both being indications of spring-migration.

From the information available, it looks as if migration takes place in the form of a series of hops, covering about 10 to 20 miles at a time, the migrating locusts alighting wherever they find sand patches covered with light vegetation for purposes of resting and feeding. Presumably it may take about a week or ten days for migrating locusts to cover the distance between the Indus and the Hab rivers, though with a strong north-east wind backing them, they may take much less time.

The concentrations of locusts that are almost always noticeable on the coastal reks of Mekran are probably to be explained as incidents of seasonal migration. In summer, locusts get into the reks from the interior from a northern or north-western direction, and in autumn and winter from a north-eastern direction. Kennedy (1939) has adduced evidence from various sources, which clearly indicates that locusts have a visual attraction to dark conspicuous objects such as trees or patches of cultivation especially in barren country. Their presence in sandy areas like the beds of dry water-courses and in rek areas, indicates that they are obviously attracted visually to such places while in flight. It is not unlikely that they likewise recognise, while in the air, the great shining barrier of the sea, and unless the wind-currents are too strong, they are presumably halted by a sight of large bodies of water. At the same time, the reks with their scrub vegetation may possibly exercise an attraction for them, which would explain why they occur in general in fairly large concentrations along the coast. While it is possible that a good many locust individuals may be carried by strong winds across the Gulf of Oman into Arabia, it is fairly certain that the majority take refuge in the rek areas, and in certain peculiar situations, such as the Rumra area (between Pasni and Ormara), which forms a narrow neck of sandy rek between the hills and the sea, specially dense concentrations have often been noticed.

Observations made in the-course of the period—1935—1938, indicate that autumnal migration probably occurs in a series of waves, which are generally concurrent with periods during which the dry north-east winds are prevalent in Sind, Baluchistan and Rajputana. In many cases, each wave of migration could be traced to a certain extent from the Rajputana area to the Lasbela area, and thence to the Ormara and Pasni reks. For instance, on 25 September 1936 a sudden decrease of locust population was noticed at Chachro, and by the end of the month an increase of locusts at Ambagh, and early in October the presence of immigrant locusts in some numbers on the Pasni reks. By the end of October, a later but more marked contingent reached the Pasni and Gwadar areas.

Very little is known in regard to the routes by which migrant locusts reach the Mekran reks from Rajputana and *vice versa*. but there is no doubt that migration is probably guided to a great extent by the direction of the prevailing winds. Predtechensky (1935-2) found in Iran that deep and long valleys played a considerable part in guiding the flights of swarms, and there is reason for the belief that the orientation of mountain valleys exerts some influence on the direction of flight of the solitaries also. In the Bolan valley, solitary locust individuals are known to pass gradually from the month of the valley at Dadhar *via* Kirtha right up to Thana Dasht and Spezand, and in their flights towards Rumra and Pasni

areas from the direction of Sind, it is very likely that migrants pass through the Kolwa valley. It must, however, be noted that in Baluchistan the direction of the valleys coincide to a great extent with that of the dominant winds. In the case of the locust populations on the Mekran coastal reks, a progressive rise of density is noticeable in autumn from east to west, and it is possible that a gradual east to west migration often occurs along the coast in winter and spring, and very probably extends into the Iranian areas. In the winter of 1936-37, there were some indications that a migration of individuals had taken place across the Gulf of Oman into the Muscat-Sharjah areas.

9. Spring Breeding in the Desert Areas

Usually the spring rainfall in the desert is not high enough to induce breeding, but in the spring of 1936 light breeding occurred in north Jaisalmer area. In the spring of 1937, fairly heavy rainfall occurred in the Jaisalmer-Bikaner areas, and as a result fairly widespread but light breeding was noted in April in many places in the northern parts of the desert, adults of the new generation being found during May. In 1935, good rainfall occurred in spring, but breeding did not follow on account of the absence of locusts in these areas.

It is rather noteworthy that, between 1933 and 1939, no spring breeding had occurred in the southern parts of the desert.

10. Parallelism of the Annual Cycle of Activities of the Solitaria and Gregaria Phases

In view of the fairly close acquaintance of the life activities of the *solitaria* phase of the desert locust obtained during nine years of continuous observations made in the Indian area of its habitat, one is now in a position to compare the annual cycle of the *solitaria* phase with what is known of that of the *gregaria* phase in India. A general outline of the annual cycle of activities of the locust in its swarming phase (*vide* pl. 33) is given at a subsequent stage in Chapter I of Section XI, which is followed, in the next chapter (Ch. II), by a fuller and more detailed review of the march of annual events, observed in past locust infestations in India. Moreover, a short summary of the general scheme of swarm activities of the 1926-1931 outbreak in India has also been given in an earlier publication [Rao, 1942].

Comparing the cycle of life activities of phase *gregaria* with that of phase *solitaria* as noted in the course of the present investigation, one notices a remarkable parallelism in the main scheme of annual events. In fact, there is the same sequence of occurrences: (1) Over-wintering followed by breeding in the winter rain areas, (2) spring migration from the coast into the interior, followed by breeding in the upland valleys, (3) summer migration to regions eastwards as a result of the development of conditions of drought in the west, (4) summer breeding in monsoon areas, and (5) autumn migration—in part at least westwards into Baluchistan owing to the autumnal rise of temperatures with the withdrawal of the monsoon current.

The main difference between the phases would seem to lie in the greater degree of activity of phase *gregaria* due in great part to its becoming subject to a mass mentality. Both *solitaria* and *gregaria* are similarly affected by the same meteorological and ecological factors, provoking them to make long distance migrations, but phase *gregaria* owing

to its occurrence in swarms is capable, under the influence of mob psychology, of reaching longer distances and covering wider areas. The area of migration of *solitaria* individuals is confined usually to the coast and interior of British and Iranian Mekran on the west, to the Rajputana desert areas on the east, but extends sometimes as far north as Chagai on the Mekran side and up to Spezand along the Bolan valley, and in the Rajputana area may extend into Patiala territory. On the other hand, swarms of *gregaria* may reach as far north as the Himalayas, as far east as Assam and as far south as the Madras Presidency. In addition, *gregaria* individuals are distinguishable from the *solitaria* type, by their higher metabolic activity and greater voracity, while in view of their passing through not more than five larval instars, they have generally a shorter life-history.

CHAPTER II

SEASONAL MIGRATION AMONG THE SOLITARIES

DURING the earlier stages of the present investigation, the generally accepted opinion was that the *solitary phase* adult lived not only a non-gregarious life, but also led, on the whole, a sedentary existence in its breeding grounds, its movements being confined only to short flights within the area. It was only when it increased in numbers as a result of heavy breeding, and swarms were built up, that a migratory tendency became manifested, long distances being covered to reach the zone of invasion areas. It was also considered that long-distance migration was a necessary precedent in the process of sex-maturation of the *gregaria* phase. In short, the capacity for long-distance migration was closely linked up with the *phase gregaria.*

In the course of the surveys conducted during the period, 1931 to 1934, however, numerous sundry observations brought to light various anomalies in the distribution of locusts, which appeared to be difficult of explanation unless the *solitaria* adult could be credited with powers of migration. For instance, in the 'rek' areas of Mekran, locusts were found disappearing altogether, whenever a failure of rainfall occurred, but there was no evidence to show that the disappearance was due to death by starvation; on the other hand, they were found re-appearing in appreciably good numbers when good rains fell. In one particular case, no locusts were noticeable during the first three weeks of May, 1932 at Pasni in consequence of a general failure of winter rains, but following the occurrence of wide-spread dust-storms originating in the interior of Mekran on 24 May, numerous specimens of bright yellow locusts were found appearing on the reks, and subsequently also pink-coloured ones during June. As many of these included recently fledged forms as well as individuals of the *gregaria* phase, not known to have been produced on the coastal areas, it is obvious that they had all been conveyed there by the winds from the hinterland. Again, in certain other instances, locusts were found, at certain parts of the year, in good numbers along the fringes of the Sind-Rajputana desert; but after a short time none was to be seen there, whereas they were present in fair numbers in the interior. It was, however, not until the remarkable locust incursion of July 1935 had clearly demonstrated the powers of long distance flight possessed by *solitaria* individuals, that it was possible to recognize that migratory movements at the change of the seasons formed one of the regular features of the life of *solitary* phase locusts.

A full account of the various lines of evidence in regard to the existence of migration among the *solitaries* was given by the writer in 1936 (Rao, 1936, 1937, I). Data that have since become accumulated in the course of survey work have served to confirm and strengthen the hypothesis of individual migration, and it is proposed to record briefly all the available evidence on the subject.

All the evidence gathered in support of migration among the *solitaries* may be classified as under:

I. *Inductional evidence,* based on:—

1. Seasonal distribution of locusts during the year;

2. Fluctuation of population at particular places during the year;

3. Biometrical evidence; and

4. External marks provided by ectoparasites etc.

II. *Direct evidence,* based on:—

1. Powers of high flying of individual locusts; and

2. Recovery of marked individuals.

I. Inductional Evidence

1. *Seasonal distribution of locusts in the Indian area.* In the course of a study of the distribution of locusts during the period, 1931 to 1938, detailed information in regard to their relative abundance and breeding could be obtained for all the different areas only from 1934. The data gathered have been graphically depicted in two half-yearly maps for each year:—One map indicating the locust situation during the winter-spring period, December to June, and the other during the summer-autumn period, July to November. In each map the populations belonging to the different generations of the year have been shown in distinctive colours for purposes of ready recognition. (Pl. 34-38 for years 1934 to 1938).

A comparative examination of Maps (a) and (b) of the years 1934 to 1938 would show at a glance that the actual areas of distribution of the desert locust in the Indian region are located in two distinct parts: (1) a western part comprised mostly of the southern areas of Baluchistan and (2) an eastern, made up of the desert areas of Sind and Rajputana, the two being separated by the alluvial region of the Sind valley, in which there is usually little breeding.

It is also apparent that, in the *first half* of the year, the locust population is comparatively sparse, and breeding extremely rare, in the eastern areas of habitat, (in fact, during the winter-spring period of 1934-1935 and 1938-1939, locusts were practically absent), whereas the population is fairly high in the western ones and breeding is generally observable in most years—with the exception of 1934, a year of failure of winter rainfall. In the *second part* of the year, on the other hand, it is seen that the locust population is definitely smaller in the western areas and breeding is quite exceptional, whereas in the eastern, the population is usually much higher and fairly extensive breeding also occurs, except in a year of monsoon failure like 1938.

The occurrence of locust activity alternately in the western and eastern areas of the Indian region of infestation in the earlier and the latter parts of the year respectively, is to be correlated with the circumstance that the western areas of habitat fall within the zone of winter rainfall, while the eastern areas (in which Lasbela is also to be included) are subject to the influence of the monsoon and are thus regions of summer precipitation. In the desert areas, locusts begin to appear from May onwards, after an absence of over three months, and breeding occurs in July-August after rainfall, while in the western reks, locusts of a recently developed generation begin to appear during the autumn

and winter months and breeding occurs in spring. Such an alternation of breeding in the winter and summer rainfall regions in the appropriate seasons would appear to be based on a transference of populations from one region to the other at the change of the seasons. A biometrical analysis of the locust populations found in the different parts of the Indian region has shown that such a seasonal exchange of populations between the winter and summer rain areas is really based on facts, since there is a definite identity of fácies between the locusts bred in spring in the west and those appearing at the commencement of the monsoon in the eastern areas, and between those bred in summer in the desert and those found appearing in the western rek areas at the end of autumn.

2. *Fluctuation of population density during the year.* In connection with a study of the seasonal increase or decrease of population in the different parts of the locust habitat in India, typical centres of the various areas were kept under continuous observation throughout the year by carrying out periodical local surveys:—(1) Pasni: as a type of the western rek areas, subject to winter rainfall, (2) Ambagh: typical of the eastern reks, subject to summer rains, (3) Chachro: typical of the southern areas of the Sind-Rajputana desert, (4) Nokh: typical of the northern parts of the desert, and (5) Sardarshahr: typical of the north-eastern parts of the desert.

On the basis of the results of the periodical local surveys, the average population density per sq. mile per fortnight was worked out for each centre, and graphs showing the fluctuation of population per fortnight during a series of years have been attached for purposes of comparison and study. (Graphs I & II; *vide* Text Figs. 20 and 21).

In case the population density were dependent solely on local multiplication, the fluctuation graph would be a fairly simple matter showing a rise in the wake of local breeding and a gradual fall with the advance of the season, denoting a depletion of numbers due to the action of adverse climatic conditions and of various natural enemies. On the other hand, various sudden rises and falls, obviously unconnected with local breeding, are noticeable in the graphs, and apparently these fluctuations could not have been caused by any factor other than an influx or efflux of migrating individuals, giving rise to a temporary increase or decrease of population density at the centres concerned.

At Pasni, for instance, (Graph I; Text Fig. 20), there was no rainfall in the winter-spring season of 1931-32, and there was no local breeding. Nevertheless, there was a sudden rise of population in May, which was clearly due to the appearance of numerous bright yellow forms, and later on of pink-coloured ones, from the interior of Mekran. In 1934 and 1937 too, although there was no local spring breeding around Pasni, there was a light, but distinct, rise of population in May-June obviously caused by an influx of locusts from outside.

In 1935, there was heavy breeding at Pasni in March, April and May in the wake of heavy rainfall, bringing about a rise of population density in April-May, but by June there was a perceptible fall. This was, however followed in July by a sudden and extraordinary rise of density, evidently due to the incursion of a population characterized by a high proportion of *gregaria* and *transiens* forms, many of which were pink or

yellow in colour. In the autumn months, again, a certain rise of population is noticed at Pasni, in spite of an absence of local summer breeding, and as the individuals met with at this time mostly belonged to a recently developed brood, predominantly solitaria in facies, this circumstance forms fairly conclusive evidence that they were migrants from the Rajputana areas where monsoon breeding had occurred in summer.

At Ambagh, which is a summer brood area, fairly good numbers of locusts are generally met with in the winter months, as a result of over-wintering. These, however, disappear generally by April. By June, and sometimes even during May, a rise in population occurs apparently due to an immigration from the western areas. With the fall of monsoon showers in June-July, breeding ensues and causes a further rise of population, by September-October. Although breeding ceases by middle of October, the rise of density still continues in November-December as a result of an influx of population from the eastern areas. This was clearly demonstrated in 1935, when in spite of an absence of breeding due to the failure of the monsoon a conspicuous influx of clear-winged *solitaria* forms from the desert areas was noticed in October-November.

In the Rajputana desert areas, few locusts are to be found in the winter-spring months (Graph II; Text Fig. 21), except when over-wintering occurs, as in 1936 and 1938 at Chachro and in 1937 at Nokh. A distinct rise of population is noticeable in June-July evidently due to an immigration of locusts from the western areas. In 1935, the rise of population was specially conspicuous in July at Chachro and Nokh as a result of the widespread locust incursion noticed over most of the locust habitat. In most years, there is a distinct rise of population between September and November, as a result of locust multiplication during the monsoon rains. In 1938, on the other hand, when the monsoon failed in most parts of the desert, there was little rise of population. In 1937, a rise of population was observed at Chachro in September, which was due to an immigration from eastern areas. By December, the major part of the population usually disappears from the desert areas, except when late breeding takes place, (as had happened in 1936 and 1937), in which case over-wintering generally occurs.

3. *Biometrical evidence.* Most of the collections of locusts made in the course of the surveys carried out between 1931 and 1938 were subjected to a close biometrical examination in the course of which, colour notes and measurements were recorded. In making a study of the populations found at various times in the different areas, locusts collected at a particular season from a particular area were grouped together for purposes of biometrical analysis, and the index was determined by working out the relative percentage in regard to (1) the phase ratios (mainly the Elytron/Femur ratio) and (2) the number of the eye-stripes. In the table attached, all the available information in regard to the facies of the population found in the different seasons of the year in the Mekran, Lasbela and Sind-Rajputana areas in successive years have been arranged so as to show their affinities with one another. (See Text Fig. 22).

From the table appended, it is seen that there is, on the whole, much affinity of character between the locust populations found at the end of the autumn in the desert areas and those noticed in winter in the Lasbela and Mekran coastal areas and similarly, between the facies of the population found at the end of the spring breeding in the Mekran area and that of the locusts noticed at the beginning of the monsoon in the desert areas. On the other hand, the biometrical facies of the parent population found

at the beginning of the breeding season in spring in Mekran, or in summer in the Sind-Rajputana desert areas, is often strikingly different from that of the generation produced in the course of breeding.

The year 1931 was characterized by the presence of swarms and naturally the collections of this period show a predominance of *gregaria* forms and of individuals with six eye-stripes.

In 1932, the population found over-wintering in Mekran and Kachhi was composed of a fairly high proportion of **gregaria** forms, but there was apparently little spring breeding in the Baluchistan areas owing to lack of rain. The migrants that appeared in May-June on the Mekran, Lasbela and Karachi coasts and in the Khairpur State were mostly composed of *gregaria* forms and had almost all six eye-stripes. On the other hand, the summer generation produced in the desert was pre-dominantly *solitaria* in character, and had a high proportion of seven-striped forms.

In 1933, no biometrical data are available for the winter and spring periods. The summer migrants in the desert areas were mostly *solitaria* with a predominance of six-stripes. The brood produced in the desert during the monsoon was predominantly solitaria in character, but while the early brood showed a dominance of six-striped forms, the later ones had a preponderance of seven-striped ones. A similar dominance of 7-stripes was noticed in the population found in October-November in the Lasbela areas also.

In 1934, there was a failure of winter rainfall in Mekran, so that there was no spring breeding.

The migrants found in the desert in May-June were mostly over-wintered forms with a facies similar to that of the population of autumn-winter 1933-34 found in the desert and Lasbela areas.

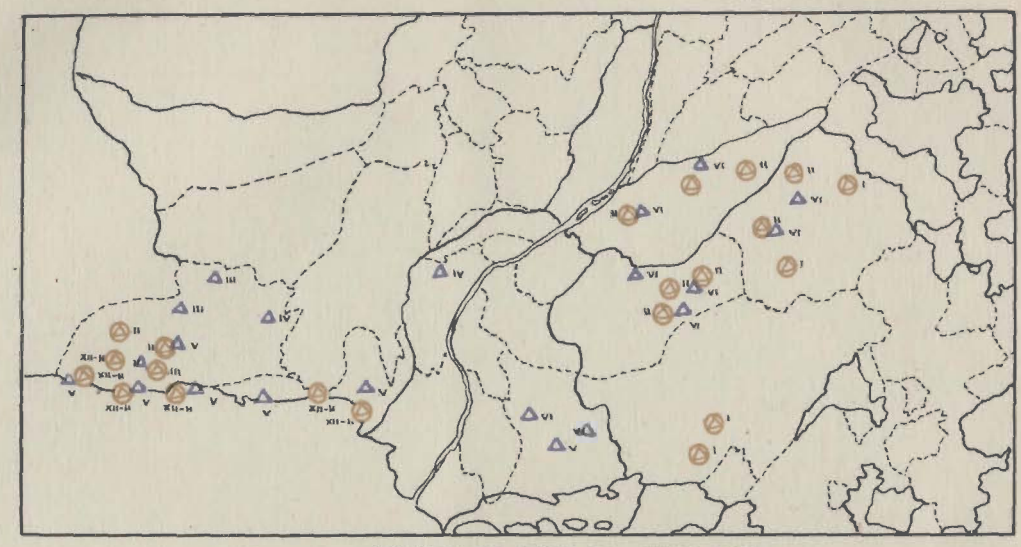
The summer generation produced in the desert was also characterized by a dominance of solitaria and 7-stripes. The population found in autumn in the desert and Lasbela had the same character, but by the beginning of winter very few locusts were to be seen in these areas. The locusts found in the Mekran reks since the middle of December 1934 were, however, marked by these same characteristics and were apparently derived from the desert brood.

In 1935, with the fall of heavy winter rains in Mekran, there was extensive breeding and the earliest batches of the spring brood were marked by the presence of ten per cent. *gregaria* and a preponderance of six-stripes, and it is somewhat significant that the earlier batches of migrants found in May-June in the Lasbela and Sind-Rajputana area were marked by this character.

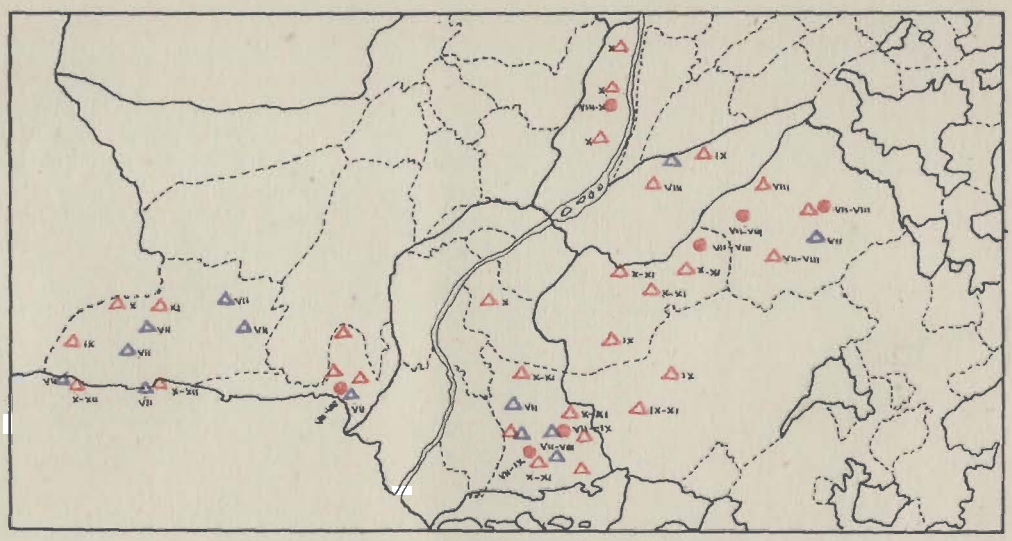
In July, there was a heavy incursion of a new brood distinguished by a preponderance of *transiens* and *gregaria* and a high dominance of six-striped forms into many parts of north-west India, the Mekran reks, the Lasbela coast and the Sind-Rajputana desert areas.

In summer, there was moderate breeding in the Rajputana areas, and the new generation was characterized by a preponderance of *solitaria* ratios, and in the later batches by a dominance of seven eye-stripes and the almost total disappearance of *gregaria*. In the Lasbela and Mekran areas, where no summer breeding occurred, forms of a recently developed brood, possessing almost the same facies as the desert brood, made their appearance (as mentioned earlier) at the end of autumn and the beginning of winter thus giving indisputable evidence of long distance migration of individuals.

LOCUST SITUATION IN 1934



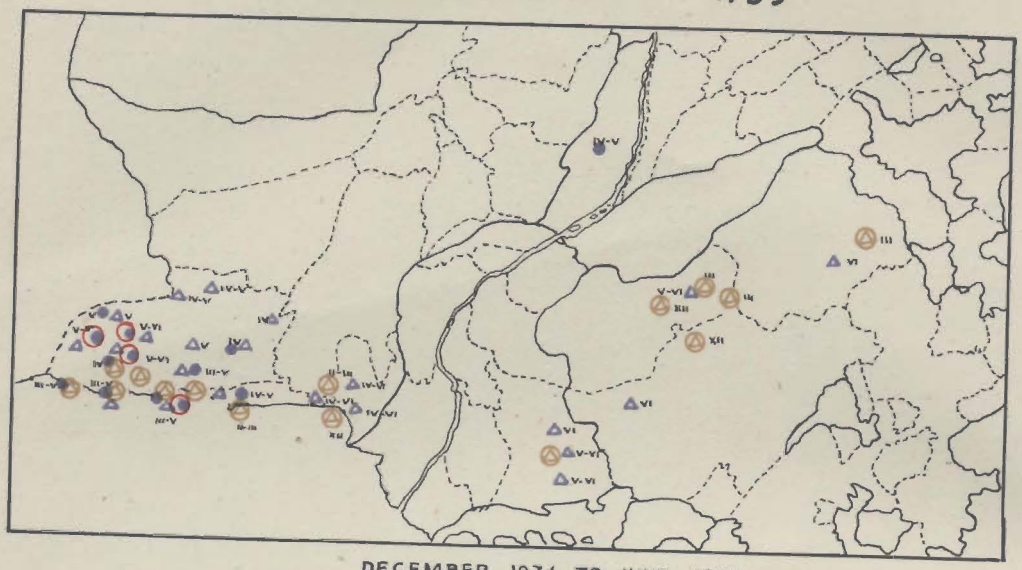
DECEMBER 1933 TO JUNE 1934



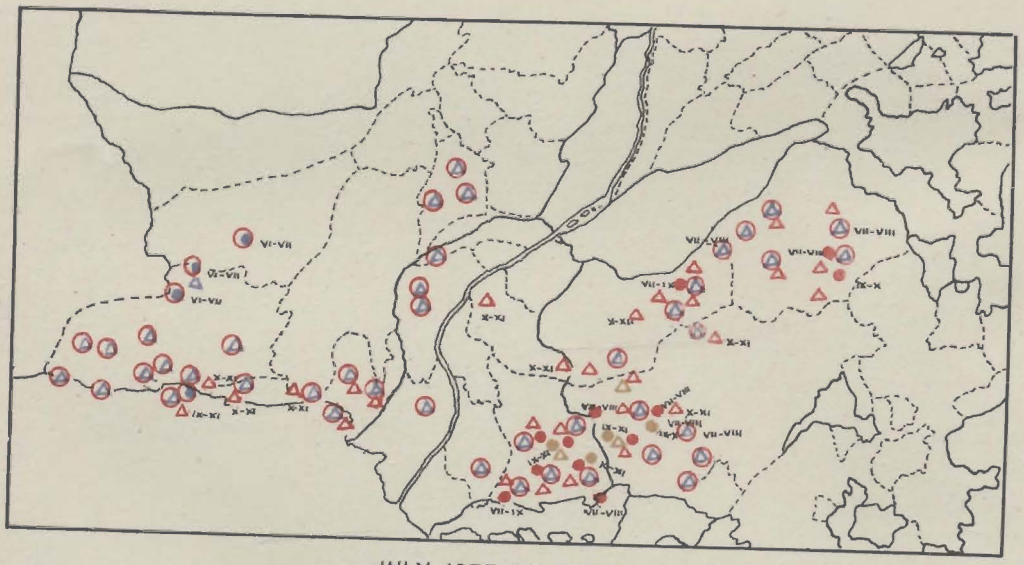
JULY 1934 TO NOVEMBER 1934

- HOPPERS OF I SPRING BROOD.
- ADULTS OF I SPRING BROOD.
- HOPPERS OF II SPRING BROOD.
- ADULTS OF II SPRING BROOD.
- HOPPERS OF I MONSOON BROOD.
- ADULTS OF I MONSOON BROOD.
- HOPPERS OF II MONSOON BROOD.
- ADULTS OF II MONSOON BROOD.
- OVERWINTERED ADULTS

LOCUST SITUATION IN 1935



DECEMBER 1934 TO JUNE 1935



JULY 1935 TO NOVEMBER 1935

- HOPPERS OF I SPRING BROOD.
- ADULTS OF I SPRING BROOD.
- HOPPERS OF II SPRING BROOD.
- ADULTS OF II SPRING BROOD.
- HOPPERS OF I MONSOON BROOD.
- ADULTS OF I MONSOON BROOD.
- HOPPERS OF II MONSOON BROOD.
- ADULTS OF II MONSOON BROOD.
- OVERWINTERED ADULTS.

In 1936, the incursion type of population persisted till March, after which it was not noticed. The new spring generation produced on the reks was marked by a dominance of *solitaria* and 6-stripes. By the end of May, however, some new forms with mauve wings were found appearing at Pasni and elsewhere—distinguished by a dominance of *transiens* and 6-striped forms and possessing a light *gregaria* element. The early migrants at Ambagh and Chachro had this type of facies, whereas the later types met with in July-August at all places were marked by the dominance of *solitaria*.

There was heavy breeding in the Rajputana area in summer and the first brood was characterized by a dominance of *solitaria* and 6-stripes, whereas the second or late brood was marked by a higher proportion of 7-stripes. These characters were reflected in the successive waves of migrants that reached Lasbela and Mekran in autumn and winter.

During 1937, there was little breeding on the Mekran coastal reks and but light breeding in the interior, and the summer migrants in the desert appear to have been derived mostly from the breeding in the interior in the Kachhi area and at the Sheh-Lakhra outbreak centre in Lasbela, They were all distinguished by a dominance of *solitaria* and six stripes.

The new generation produced in the desert, was marked by the dominance of *solitaria* and *transiens* and by a predominance of six-stripes, and this was reflected in the character of the population found reaching Lasbela and Mekran in autumn and winter.

In 1938, spring breeding was light both in Mekran and Kachhi, and there were comparatively few migrants. As the monsoon was not favourable, the summer breeding in the desert was also fairly light. Consequently, the autumn migration in Lasbela and Mekran was also light. The facies noticed throughout the year was on the whole uniform, being characterized by a comparative dominance of *solitaria* and six-striped individuals.

In the above table, an attempt has been made, by means of arrow-marks, to give graphic representation of the relationship between the populations found in the summer and winter rain areas in north-west India during the years 1931 to 1938. On the whole, the tabulated data give a fairly clear idea of the seasonal movements of locust populations from west to east or east to west with the shifting of the rain belts.

4. *Evidence furnished by natural external marks.* In a good many instances, individual locusts carry external marks, such as ectoparasites like mites and green algae, which may sometimes give a clue to their origin. In one case, the possession of the unusual number of eight stripes in the eyes was found to be of much significance.

(a) *Red Mites.* The presence of tiny mites of red colour is often noticed on the wings and bodies of various Acrididae. They are believed to be the young larvae of the Velvet Mite—*Trombidium grandissimum.* The adult mites generally live underground in the soil, and come to the surface in quite large numbers after the first heavy shower. After leading an active life for a day or two, they burrow into the soil and disappear. It is presumed that eggs are laid in the soil. Young larvae are seen in good numbers on the surface of the ground in about a month, and attach themselves to the first grasshopper or locust that they may find in the vicinity. After leading a parasitic life for sometime and growing in size, they drop to the ground for undergoing a moult. When, therefore, a locust is found to have red mites on its body, it may be taken to be a sure indication that it has come from an area where good rainfall has occurred.

In 1935, there was no summer rainfall in the Lasbela area so that there was no possibility of red mites occurring in that area, but actually a new generation of locusts carrying red mites was noticed there in the autumn months, which may be taken as presumptive evidence as to their origin from an area of good rainfall. A good many similar instances have since been noted.

(b) *Tyroglyphid Mites.* The desert locust is subject to the attack of a small vermiform mite—yet un-identified—belonging to the family Tyroglyphidae (Plate 41 Fig. 3). The mites live crowded together at the base of the wings and on the meso-notal and meta-notal areas of the thorax, and along the sides of the larger veins of the hind-wings. Whereas the mites are light cream yellow, the moult-skins of the young mites are bright white and form conspicuous white clusters on the thorax and on the wings. The adult mites, and probably also the young ones, drop from the body of infested locust and while crawling over vegetation, presumably, they attach themselves to fresh locusts that may happen to alight near by. Apparently full-grown females start a new colony on fresh hosts by laying eggs on their wings and bodies.

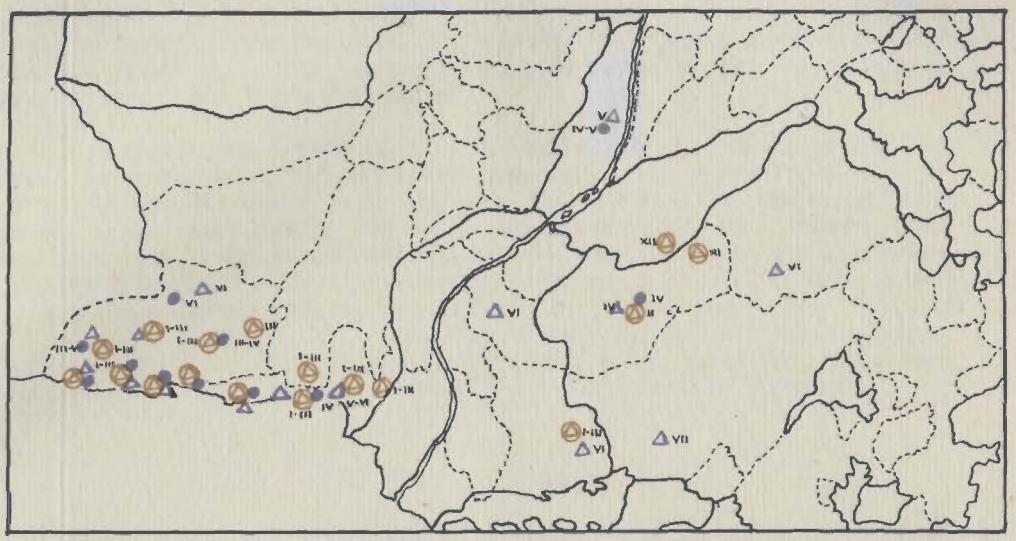
This mite has been found in largest numbers in the Bikaner-Jaisalmer areas in summer, whereas in the autumn-winter period, quite good numbers of locusts infested by Tyroglyphid mites have been collected in the Lasbela and Mekran rek areas. In 1936, several cases of infested locusts were noticed in the Rajputana desert areas, and by October-November similar infested individuals were collected at Ambagh in the Lasbela area. Later observations have, however, shown that infestation of fresh locusts may to a certain extent occur also in spring in the Mekran areas after breeding. Migrants apparently carry the infection from the spring breeding grounds to the summer brood areas and *vice-versa.*

(c) *Green Algae.* (Plate 41 Fig. 1 & 2) Wherever over-wintering of locusts has been observed, a fairly good proportion of the locust population collected therefrom has been found to carry specimens of *green algae* on their wings. It is believed that locusts pick up the spores of the algae either from the ground or from the neighbouring vegetation while over-wintering, and that during the winter, when the air is cool and moist especially after winter rainfall or during foggy weather, the spores germinate and grow on the surface of the wings. Under favourable conditions the algal growths may be quite abundant. The algae are always found on fairly old forms, and never on freshly fledged individuals. They are also never found growing in dry weather. The development of algae is most generally noticed on the moist coastal areas of Lasbela and Mekran, and to a smaller extent in the desert areas.

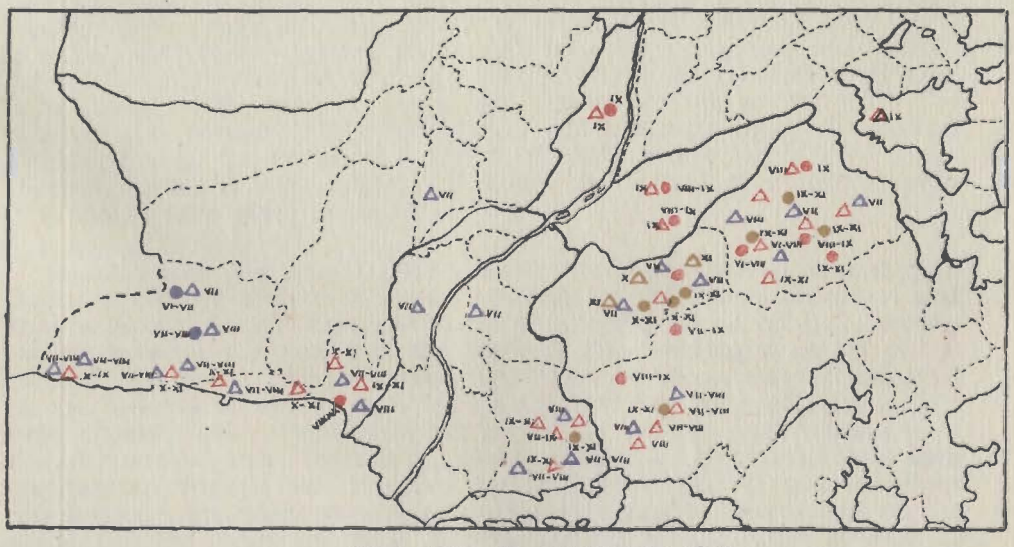
In 1937 and 1938, a few forms with green algae on the wings were found in the Kachhi-Bolan areas in April-May, and in one instance, a locust with green algae on the wings was collected in April 1938, as far north as Dalbandin. In other cases, specimens carrying algae were found in the interior of Mekran, in the Kolwa and Panjgur areas. All these may have to be considered as instances of seasonal migration from the coast to the interior, since presumably the dry conditions of the hinterland cannot be deemed to be favourable for fresh growths on new hosts. Moreover, locusts are but rarely seen in the interior of Mekran in winter.

The writer is indebted to Dr. Y. Bharadwaja, Head of the Department of Botany in the Benares Hindu University, for kindly determining the algae. He wrote as follows under date 19th January, 1941: "The algal specimen certainly belongs to the family Trentepohliaceae of the order Chaetophorales of the class Chlorophyceae. It comes close to the

LOCUST SITUATION IN 1936



DECEMBER 1935 TO JUNE 1936



JULY 1936 TO NOVEMBER 1936

- HOPPERS OF I SPRING BROOD.
- ADULTS OF I SPRING BROOD.
- HOPPERS OF II SPRING BROOD.
- ADULTS OF II SPRING BROOD.
- HOPPERS OF I MONSOON BROOD.
- ADULTS OF I MONSOON BROOD.
- HOPPERS OF II MONSOON BROOD.
- ADULTS OF II MONSOON BROOD.
- OVERWINTERED ADULTS

genus *Gomontia,* species of which have been described to be inhabiting the shells of living Mollusca. The habit of the plant and the appearance of the cells is quite like those in *Gomontia,* but then the present species appears to be much more terrestrial. The contents of the cells are rather dried up, and their actual nature is not very clear. Plants belonging to the Trentepohliacease have got the capacity for penetrating into calcareous and other sub-strata, and the wind dispersal of the sporangia is known in certain terrestrial forms".

(d) *Eight-striped Forms.* (Text Fig. 18). In 1936, the development of a fairly good number of locust individuals with eight eye-stripes was observed in the Bikaner area during July, August and September, and the production of such forms was not noticed elsewhere, and, indeed, none has been seen in the desert areas since 1936, with the exception of a single individual found in 1937. Two locusts with eight eye-stripes were found among the migrants collected at Ambagh in October-November 1936, and two more in January 1937. Since then, such forms have not been met with at Ambagh. These data clearly indicate the possibility of a long distance migration from the Bikaner area to Lasbela in autumn

II. Direct Evidence

1. *Powers of high flying among Solitaries.* In the course of locust survey work, the staff have at various times noted instances of individual locusts attempting high flights. Though, as a rule, locusts have been found making only short flights from place to place when disturbed during surveys, some of them have been noticed, especially during dry, hot weather, flying high into the air and ultimately disappearing from sight. In a few cases, however, some individuals have been observed, after reaching a fairly high altitude, to change their mind quite unaccountably and, with closed wings, make a precipitate descent to the ground with the velocity of a rocket. The celerity with which locusts reach the ground combined with the cryptic coloration of their bodies when they settle thereon, makes it very difficult to detect the arrival of migrants, even if it should take place in daylight.

Zolotarevsky and Murat (1938) record the occurrence of similar high flights in French Sudan, in Tchad territory and in Mauretania, but add that in most cases the flights were due to a forced taking off and that the locusts invariably returned to the ground after reaching a height of 100 meters. Kennedy (1939), on the other hand, mentions several instances of spontaneous taking-off observed on the Red Sea coast of Sudan. His field observations, which were supported by certain experiments in a closed room, however, led him to consider that the main stimulus to such spontaneous flights was supplied by the occurrence of general light intensity on the western sky at dusk. As already mentioned in the account of the locust incursion of 1935, the writer had noted at least 18 instances of spontaneous taking-off at dusk in the course of four different days in July 1935 at Pasni, but in no case did he find any flights directed towards the west, though the latter was brightly lit at twilight. The atmospheric temperature at this period, was about 27-28°C (81-83°F.) and the humidity also fairly high (80 per cent). The dominant wind was a strong sea-breeze from the south-west and the main direction of flight of the locusts varied between north and north-east. It appears likely that, in summer, taking off occurs mostly at dusk or during the early part of the night, though at other seasons when the temperatures are lower, flights may take place during daytime.

Interest was first aroused in the capacity of high flight possessed by locust individuals by the accidental escape of a locust from a cage on the afternoon of 11 July 1935 at Pasni. It began to soar high and soon disappeared from sight flying with the wind. As releases of a few more caged individuals confirmed this tendency, further observations were made, while making the periodical liberations of marked locusts from the top of a high dune at Pasni, in regard to the orientation of their flights in relation to the general wind-direction. As the individuals released did not readily take wing, each locust thrown by hand into the air, when they generally took flight. Several of them, however, flew only short distances, some with the wind and some against the wind, and eventually settled on the ground not far from the place of liberation, but others flew high into the air, and generally in the same direction as the prevailing wind, though each individual was observed steering its course in its own way.

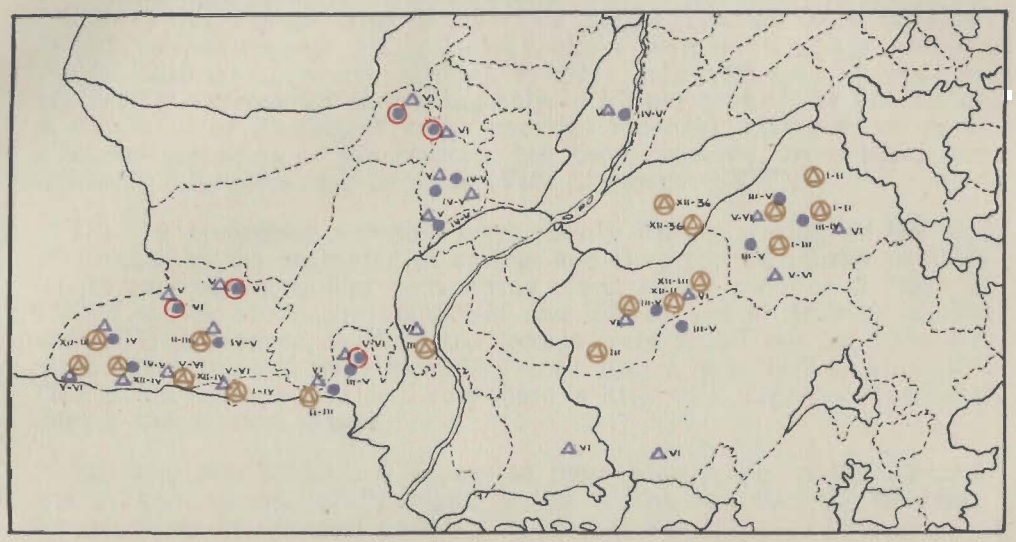
The significance of high flights was, however, not realized till the full data on the wide-spread incursion of locusts of July-August 1935 in parts of Mekran, Lasbela and Sind were available for study. In view of the circumstance that the locust population at Pasni had suddenly increased on 12th July and that the locusts noticed on and after that date consisted mostly of pink or yellow forms, with *gregaria* or *transiens* ratios—not previously met with in that area, it was evident that an influx of locusts had occurred from outside. Since swarms had not been noted anywhere around Pasni, the inference would appear to be that the rise of population had been due to an immigration of large numbers of individuals.

In this connection, it may be stated that Zolotarevsky and Murat (1938) record the sudden disappearance of Schistocerca adults in the course of survey work in Mauretania which was not explicable except on the basis of an emigration by high flights as individuals. Similarly, Kennedy (1939) in the course of an intensive study of locust ecology at Hamashiameb on the Red Sea coast of Sudan in the winter-spring period of 1936-37, records two instances where the population diminished very considerably in the course of a few days, of which the only explanation, according to him, would be individual emigration.

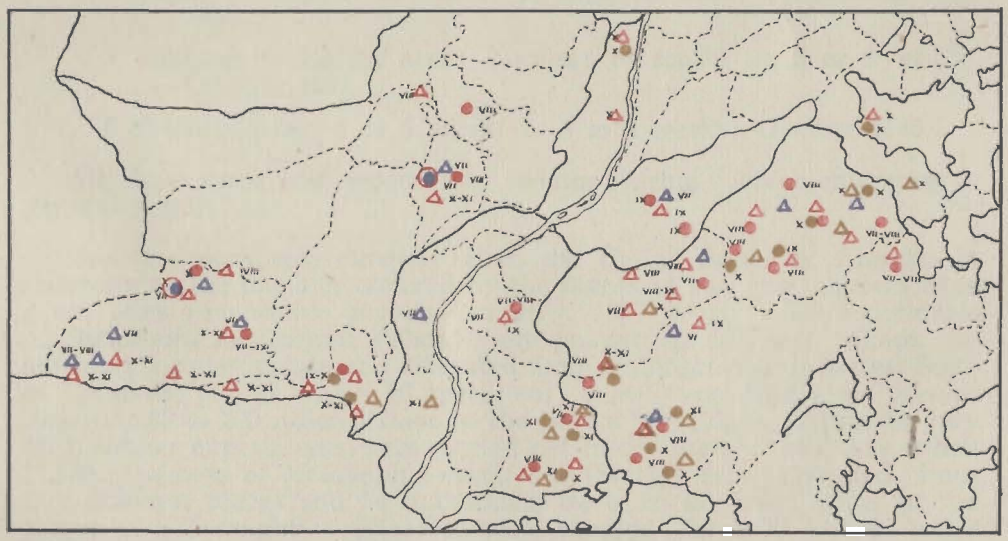
2. *Experiments with the Marketing of Individuals.* Although a considerable amount of circumstantial evidence has accumulated to indicate the occurrence of migration among the solitary locusts, the only direct proof of its existence would be the recovery of marked individuals from distant places. As per suggestions made by Dr. B. P. Uvarov to the writer at London in 1934, cellulose paints were tried for marking locusts before liberation. The first experiment was made at Pasni on 29 December 1934 with the liberation of five marked individuals, of which one was recaptured in January 1935 not far from the place of release about 25 days later. Subsequently a regular system of marking locusts collected during surveys and liberating them was adopted at Pasni, and later on at other localities.

At first, marks indicating the month of liberation were made with cellulose paints on the pronotum of locusts, but it was found that the paint peeled off after a time. Later on, painting the hind-wings was tried and a similar result was obtained, if the paint were applied thick. Ultimately, a system of lightly painting the figure of the month in arabic numerals on the hind-wings was adopted, the left wing receiving the mark during the first fortnight of the month and the right wing during the second. In addition, a bit of coloured silk thread was tied at the distal end of the femora to enable the staff to spot them easily in the

LOCUST SITUATION IN 1937



DECEMBER 1936 TO JUNE 1937



JULY 1937 TO NOVEMBER 1937

- HOPPERS OF I SPRING BROOD.
- ADULTS OF I SPRING BROOD.
- HOPPERS OF II SPRING BROOD.
- ADULTS OF II SPRING BROOD.
- HOPPERS OF I MONSOON BROOD.
- ADULTS OF I MONSOON BROOD.
- HOPPERS OF II MONSOON BROOD.
- ADULTS OF II MONSOON BROOD.
- OVERWINTERED ADULTS.

field. A similar system was adopted as far as possible at Ambagh and other locust stations, different colours being used to distinguish the locusts released at these stations, for instance, blue being used at Pasni, red at Ambagh, green at Chachro, and so on. In the course of the period —1935 to 1938, quite large numbers of marked locusts were liberated in the various regions where locust surveys were in progress. On the whole, 6,210 locusts were set free, of which, however, only 82 were re-captured the recoveries amounting only to 1·3 per cent of the liberations. A statement of liberations and recoveries recorded during these years, classified according to the seasons, has been prepared, from which the following inferences may be made (*Vide* STATEMENT—XIV).

(1) The recoveries recorded were mostly during winter, or the end of autumn or the beginning of spring, and they pertain mostly to areas where over-wintering had been taking place, as for instance at Nokh in 1936-37 winter, at Chachro in 1935-36 and 1937-38, and at Ambagh in 1936 and 1937. Moreover, most of the locusts were found not far from the place of release, and some were recovered after a lapse of 3 to 4 months. This would indicate that as a rule there is little of a migratory tendency during the winter- season.

(2) Very few recoveries appear to have been made in the summer and autumn season, which might be due to the fact that the tendency for migration is strongest at this part of the year.

(3) The only significant data are the following:—

1. Pasni to Rumra: 20 miles: to east: in about a week in May, 1935.
2. Ambagh to Rajbar area: 8 miles: to south: in 5 or 6 weeks: October 1937.
3. Gwadar reku: 4 or 5 miles: in 3 to 4 weeks: October 1936.

All these cases had occurred in months during which migration is generally active.

Recent experiments carried out in the United States of America in determining the distance covered by the flights of two grasshoppers have given very remarkable results. In July, 1937 nearly 3,000 individuals of *Dissosteira longipennis* (Thos.) were painted in different colours by spraying lacquer paints and liberated from different places in the State of Colorado, out of which 16 specimens were recovered from various localities 50 to 175 miles distant in the course of 20 days. Again in July 1938, similar experiments were carried out in the State of Montana, when 17,500 specimens of *Melanoplus mexicanus* (Sauss.) were liberated from five different places and 14 individuals were, in all, re-collected in the course of a fortnight from distances ranging from 30 to 230 miles [Willies, 1939]. A few had reached Canadian territory beyond the boundaries of the state.

Similarly, a liberation of over 100,000 painted specimens of *Melanoplus mexicanus* (Sauss.) was made on 17 July 1938 from the Agricultural Station, Fargo, North Dakota, out of which six specimens were recovered in the course of one to three weeks from localities 20 to 215 miles distant [Munro and Saugstad, 1938]. The migrations are said to have averaged 17 miles per day, and flights over 50 miles per day were recorded. It was reported that the flights coincided generally with the prevailing wind-directions.

STATEMENT XIV

Statement showing results of Experiments with the Liberation of Marked Locusts

Area	Details of liberation			Particulars of recoveries, if any			
	Time of liberation		Number liberated	Number recovered	Date and place of recovery	Distance from place of release	Interval between liberation and recover y
	Year	Month					
I. WINTER SEASON (DECEMBER-FEBRUARY)							
Mekran . . .	1935 .	December, 1934.	5	1	23rd January, 1935	Near place of liberation (Pasni).	25 days.
		February	15	1	6th March 1935	Do. (Pasni).	10 days.
	1936 .	February .	5	1	16th March, 1936 .	Within ½ mile (Pasni).	20 days.
	1937	December, 1936.	10 (P-Ormara)	Nil	..	..	..
		February	7 (Ormara .		..	..	..
	1938 .	January	50	Nil	..	..	..
		February .	9	Nil	..	..	..

Lasbela	1935	..	Nil	..	..	..	..
	1936	February	67	Nil	..	..	..
	1937	December	104	1	26th December, 1936	Near place of liberation (Ambagh).	1 week.
		January	18	1	27th February .	2 miles.	6 weeks.
		February	27	Nil	..	..	..
	1938	December, 1937	83	1	27th January	Near place of liberation (Ambagh).	8 weeks.
		January	152	3	1 on 4th February 1 on 10th February 1 on 11th March.	Do. Do. Do.	2 weeks. 3 weeks. 7 weeks.
		February	94	6	10th and 24th February, 4th and 14th March and 6th April.	Do.	1, 1, 2, 5, 5 & 8 weeks respectively.
Chachro	1935	..	Nil	..	..	..	..
	1936	..	Nil	..	..	..	..
	1937	..	Nil	..	..	..	..
	1938	Dec. 1937	111	Nil	..	..	..
		January	30	1	23rd February N.E. of place of liberation.	1/4 mile.	1 week.
		February	70	3	1 on 23rd February 1 on 28th February 1 on 23rd February	1/8 mile. 1/4 mile. 1/8 mile.	2 weeks. 3 weeks. 1 week.
Nokh	1935	..	Nil	..	..	..	..
	1936	..	Nil	..	..	..	..
	1937	Dec. 1936	184	11	1 on 4th December 10 on 14th, 23rd and 25th December.	1/8 mile. Near place of liberation.	Less than 1 week 1 to 3 weeks.
		January	46	1	19th January	Do.	1 week.
		February	111	1	16th February	Do.	3 weeks.
	1938	December	4	Nil	..	..	..

STATEMENT XIV—*contd*

Statement showing results of Experiments with the Liberation of Marked Locusts

Area	Details of liberation			Particulars of recoveries, if any			
	Time of liberation		Number liberated	Number recovered	Date and place of recovery	Distance from place of release	Interval between liberation and recovery
	Year	Month					
II. SPRING SEASON (MARCH TO MAY)							
Mekran . . .	1935	April	150	5	27th and 22nd April and 6th, 8th and 10th May (Pasni)	All within a mile of the place of liberation.	
		May	30	3	1 on 17th May N.E. (Rumra).	20 miles.	1 week.
					2 on 20th and 21st May (Edasti and Ekmach).	1 mile.	1 to 2 weeks.
	1936	March	41	1	16th March (Pasni)	Near place of liberation.	1 to 2 weeks.
		April	5	Nil	..	..	..
		May	28	2	20th June (Pasni).	Near place of liberation.	3 to 4 weeks.
	1937	..	Nil.	..	..	..	..
	1938	March	12	2	28th and 30th March (Gwadar).	Near place of liberation.	2 weeks.
		April	8				
			Ormara	Nil	..	..	..
			Gwadar 31	Nil	..	..	..
		May	Pasni				

	1935	..	Nil	..	..	..	
		March	50	1	15th March.	Near place of liberation.	1 week.
Lasbela . . .	1936	April	2	Nil	..	..	..
		May	50	1	17th May	Near place of liberation.	1 to 2 weeks
	1937	..	Nil	..	..	..	..
	1938	April	7	Nil	..	..	..
Chachro . . .	1935	..	Nil	..	..	..	..
	1936	March	3	Nil	..	..	..
	1937	..	Nil	..	..	..	..
	1938	March	24	Nil	..	..	..
		April	2	Nil	..	..	..
	1935	..	Nil	..	..	..	..
	1936	..	Nil	..	..	..	..
Nokh	1937	March	5	Nil	..	..	..
	1938	..	Nil	..	..	..	..

STATEMENT XIV—*contd.*

Statement showing results of Experiments with the Liberation of Marked Locusts—contd.

Area	Details of liberation			Particulars of recoveries, if any.			
	Time of liberation		Number liberated	Number recovered	Date and place of recovery	Distance from place of release	Interval between Liberation and recovery
	Year	Month					
III. SUMMER SEASON (JUNE TO AUGUST)							
	1935	June	25	1	Early July (Pasni)	Near place of liberaton.	About 3 to 4 weeks.
		July	Some	Nil	..	..	..
		August	Some	Nil	..	..	..
Mekran . . .	1946	June	62 Pasni-Gwadar	Nil	..	..	..
		July	38 Pasni-Gwadar Ormara	Nil	..	..	..
		August	37 Pasni-Gwadar	Nil	..	..	..
	1937	..	Nil	..	..	..	..
	1938	June	30 Pasni	Nil	..	..	..
		July	14 Pasni	Nil	..	..	..
		August	2 Pasni	Nil	..	..	..

	1935	..	Nil	..	..	..	..
	1936	July	16	Nil	..	..	..
		August		Nil	..	..	..
Lasbela . . .	1937	June	186	2	25th June	½ mile in each case. (Shah Lakhra).	11 days.
		July	28	Nil	..	..	..
		August	110	1	19th September	Near place of liberation (Ambagh).	3 to 4 weeks.
	1938	..	Nil	..	..	..	..
	1935	..	Nil	..	..	..	..
Chachro . . .	1936	August	34	Nil	..	..	..
	1937	August	45	Nil	..	..	..
	1938	...	Nil	..	..	..	..
	1935	..		-	..	..	
Nokh	1936	..	Nil	..	..	..	..
	1937	June	108	1	28th June. S.E.	1 mile.	2 weeks.
		July	24	Nil	..	..	..
		August	97	Nil	..	..	..
	1938	July	4	Nil	..	..	..
		August	3	Nil	..	..	..

STATEMENT XIV—*contd.*

Statement showing results of Experiments with the Liberation of Marked Locusts—contd.

Area	Details of liberation			Particulars of recoveries, if any			
	Time of liberation		Number liberated	Number recovered	Date and place of recovery	Distance from place of release	Interval between liberation and recovery
	Year	Month					
IV. AUTUMN SEASON (SEPTEMBER TO NOVEMBER)							
Mekran	1935	September	Some	Nil	..	..	..
	1936	September	16	1	2nd October (Gwadar-Jiwani)	4 to 5 miles.	3 to 4 weeks.
		November	5 Ormara.	Nil	..	..	..
	1937	October	83	Nil	..	..	..
		November	122	Nil	..	..	..
	1938	October	3	Nil	..	..	..

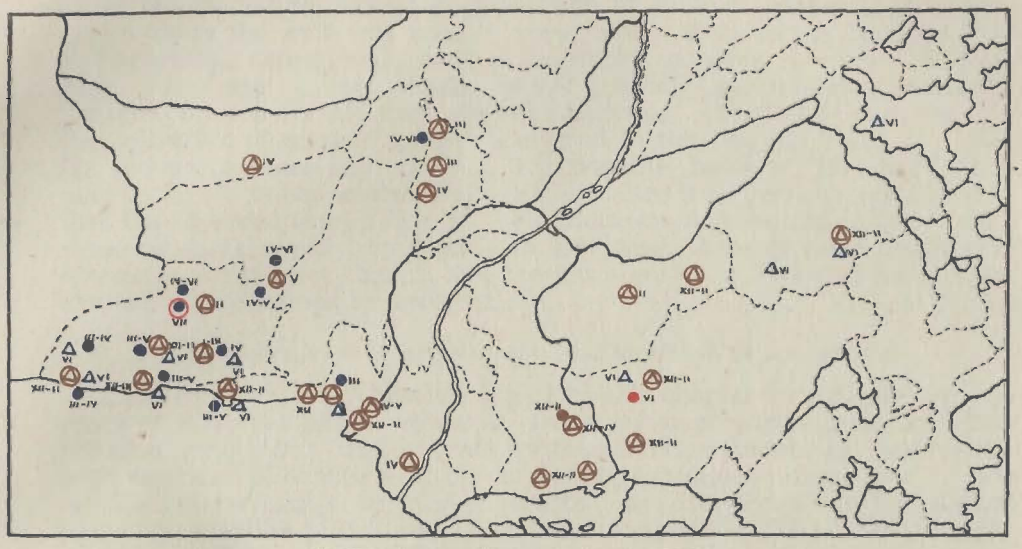
	1935	..	Nil	..	..	..	..
	1936	September	32	3	13th Oct. and 3rd and 10th November	Near place of liberation. Ambagh	4 to 5 weeks, 5 to 9 weeks and 2 to 2 weeks, 1 to 2 and 5 to 6 weeks.
		October	70	4	28th Oct. 3rd and 25th November.	Do.	1 week, 4 weeks and 6 weeks.
		November	Some	3	10th Nov., 17th Dec.	Do.	
Lasbela . . .	1937	September	755	9	1 on 15th October (Rajbar).	8 miles.	5 to 6 weeks.
					1 on 18th October (Bagori).	3 miles.	3 to 4 weeks.
					1 on 26th September (Bagori)	1½ miles.	2 weeks.
					1 on 17th January	Near place of liberation.	17 to 18 weeks.
					5 on 19th September and 17th November	Do.	..
		October	669	3	5 on 25th October 2nd Nov., 21st Jan., 27th January.	Do.	1, 3 to 4, 14 and 13 to 14 weeks.
		November	863	5	3 on 29th Jan. (Bagori)	½ mile.	3 months.
					9th Nov., 26th Nov., 6th Dec. and 1st January.	Do.	1, 2 to 3, 4 and 3 weeks.
	1938	..	Nil	..	..	..	..

STATEMENT XIV—*concld.*

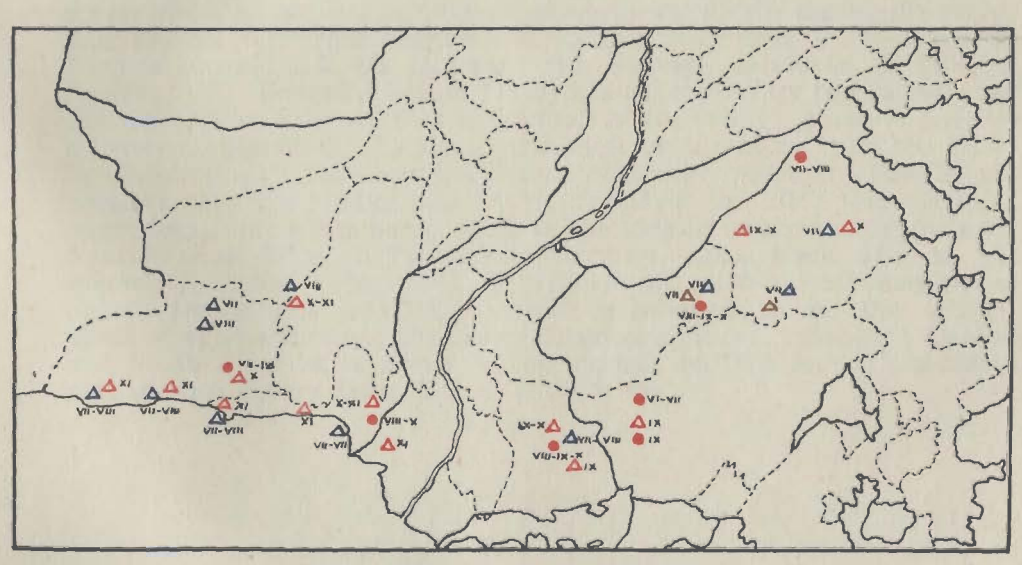
Statement showing results of Experiments with liberation of Marked Locusts—concld.

Area	Details of liberation			Particulars of recoveries, if any.			
	Time of liberation		Number liberated	Number recovered	Date and place of recovery	Distance from place of release	Interval between liberation and recovery
	Year	Months					
Chachro	1935	September	10	Nil	..	..	..
		October	18	Nil	..	..	..
		November	19	3	5th Dec. 20th Dec., 8th March.	Near place of liberation.	2 and 5 weeks and 3½ months.
	1936	September	48	Nil	..	..	..
	1937	September	112	Nil	..	..	..
		October	87	Nil	..	..	..
		November	108	Nil	..	..	..
	1938	September	4	Nil	..	..	..
Nokh	1935	October	30	Nil	..	..	..
	1936	October	75	1	19th November N.E.	½ mile.	4 weeks.
		November	19[illegible]	Nil	..	..	..
	1937	September	289	1	18th September	Near place of liberation.	1 to 2 weeks.
		October	79	Nil	..	..	..
		November	4	Nil	..	..	..
	1938	October	6	Nil	..	..	..

LOCUST SITUATION IN 1938



DECEMBER 1937 TO JUNE 1938



JULY 1938 TO NOVEMBER 1938

- ● HOPPERS OF I SPRING BROOD.
- △ ADULTS OF I SPRING BROOD.
- ◉ HOPPERS OF II SPRING BROOD.
- ⊖ ADULTS OF II SPRING BROOD.
- ● HOPPERS OF I MONSOON BROOD.
- △ ADULTS OF I MONSOON BROOD.
- ● HOPPERS OF II MONSOON BROOD.
- △ ADULTS OF II MONSOON BROOD.
- ⊖ OVERWINTERED ADULTS.

It is difficult to say why the experiments conducted in India should have been attended with so little of success, compared with similar experiments in America, though perhaps the circumstance that the number of marked locust individuals liberated was comparatively small, but this could not be helped since the population of solitary phase individuals met with in the field was usually very small. Considering the fact that the liberation experiments had to be made in very sparsely inhabited country and that solitary locusts do not generally attract the attention of lay-men, the results obtained are not surprising. Offering of rewards for the collection of marked locusts was tried in the Lasbela State in 1936, but did not produce any results. It is possible, however, that the failure may be due to faulty methods of marking, since it is, perhaps, not unlikely that the coloured thread tied on the femora might have led to their being detected more readily by birds. In any case, there is little doubt that success is a matter of chance, and the few significant data that have been secured were obtained by accident.

Evidence of migration of the 'Solitaries' in other locusts

The term 'solitaries' has been used in this chapter to indicate individuals of whatever phase—*solitaria, transiens* or *gregaria*—from the biometrical view-point, that migrate by themselves without any association with swarms. Evidence of such individual migration has now been established for many species of locusts. As mentioned in an earlier paragraph, Willis [1939] and Munro and Saugstad [1938] have brought evidence of the capacity of individuals of two swarming American grasshoppers—*Melanoplus mexicanus* (Sauss.) and *Dissosteira longipennis* (Thos.) to migrate distances of over 200 miles in some cases. In the course of locust surveys carried out in north-west India during the period 1931 to 1939, numerous instances of 'solitary' migration were noted in *Locusta migratoria* L. ph. *solitaria*, and *Patanga succincta* L. [Rao & Bhatia, 1939]. Recently, Waloff [1940] has collected very convincing evidence that goes to prove that individuals of the solitary phase of *Locusta migratoria migratoria* (L) are in the habit of migrating from the Black Sea borders as far north as the British Isles every summer. She further remarks "Definite indications were obtained in 1936 that seasonal migrations, which commonly occur in the case of swarms of *Nomadacris septemfasciata* Serv. in Tanganyika territory, take place also in ph. *solitaria* [Lea and Webb, 1936]. Finally, an incursion of great numbers of *Schistocerca americana* (Drury), which is believed to be the solitary phase of the swarming *Schistocera paranensis* Burm., inhabiting Central and South America, occurred in the autumn of 1939 into the southern part of New Jersey State, U.S.A. [Fox, 1940]".

CHAPTER III

THE LOCATING OF OUT-BREAK CENTRES IN NORTH-WEST INDIA

A STUDY of the past locust invasions in India has shown that they have been appearing in cycles separated from one another by intervals in which no locust swarms are to be seen. The observations made during the last interval, which began in 1932, have made it clear that, in spite of the disappearance of swarms, the locust has always been present in the desert breeding grounds leading a solitary phase life. The results of the present investigation have shown that the reaction of the *solitaria* phase locust to weather conditions is more or less similar to that of the *gregaria* phase as regards breeding and migration. Fairly clear indications have also been obtained as to how the transformation of phase is probably brought about and how a new cycle of infestation may be brought into existence.

The experience gathered during the last infestation has shown that it is difficult to check a locust outbreak, when once swarming has actually begun, and that the best plan would be to keep a watch over the outbreak centres of the locust and control the initial swarms as they form, and thus prevent the pest from breaking out. The ultimate aim of locust investigations being that of devising methods for preventing future outbreaks, a survey was made, in the course of locust observation work, of all those localities where conditions favourable for the formation of outbreak centres in the Mekran and Lasbela areas were likely to come into existence. As an intimate knowledge of their location would, obviously, be necessary for detecting the incipient swarms and destroying them before they could start a new cycle, all likely places were marked on large scale maps for purposes of reference, a copy of which is reproduced on a reduced scale in Fig. 23.

From the data collected in the course of nine years of field observations on the solitary phase of the locust in the Indian area, the following would appear to be the general sequence of events in respect of conditions favourable to the starting of a new cycle of infestation in north-west India:—

1. Granting that winter rainfall has been early and heavy in the western areas of Baluchistan and that a fairly high *solitaria* population is present over-wintering in the comparatively warm climate of the Mekran coast, a fairly wide-spread breeding might be expected to occur on the sandy rek areas. The new generation would begin to appear in good numbers by the end of March or the beginning of April.

2. By February, with the general rise of temperature, locusts would begin to migrate from the coast into the valleys of the hinterland. By March most of the old over-wintered individuals would have reached the interior, and in April and May, the new generation from the coastal reks would also be following them. The interior of Mekran being a hilly area, mostly either rocky or stony, soft soils—such as fine silts or sandy loams—are to be met with only at the bottom of the valleys, and in some places, small mounds of fine, wind-blown silt may also be found, either on the banks of streams and or along the hill flanks. Much of the cultivation (jowar in summer and wheat or small millets in spring), is found on silt or sand loams generally along the banks of water courses. Locusts migrating into the interior are presumably attracted to the cultivated fields, mostly jowar, and as, the soft wet soils in such places offer

suitable locations for egg-laying, crowded oviposition is apparently induced. The hoppers hatching therefrom would appear to congregate in the cultivation or on the weeds round about, and undergo a transformation of phase there.

3. Such outbreak centres may form, not only in Mekran, but also in Lasbela, in Kachhi and in the hill-valleys of Upper Baluchistan like the Bolan area, and possibly in similar situations in Iranian Mekran.

4. With the development of dry weather in summer, most of the locusts produced in Baluchistan and southern Iran would appear to migrate eastwards into Sind, Rajputana and the Punjab, where they begin to appear in May-June. The migration generally continues into July and August, and on the whole, quite a large body of migrants become congregated in suitable parts of the desert area, where breeding would appear to begin in July, in the event of good rainfall, and the new generation of locusts produced in the desert might be found appearing by the end of August. Should fairly good rainfall occur in August and September, a second generation would be produced in the desert, and very often the depressions that pass over the desert from east to west may carry locusts from the northern and eastern parts of the desert into the south-western or western parts and cause the formation of dense concentrations which would, after breeding, lead to the production of large swarms.

5. With the development of dry weather in September-October, the swarms produced in the Rajputana area would become dispersed, a good many leaving the area westwards into the Sind-Baluchistan area, where they over-winter and breed in the following spring.

From the above, it is obvious, that the real danger points are (1) the formation of outbreak centres in the interior of Baluchistan in late spring and (2) the intensive multiplication in the desert, especially, in the south-western parts, in September-October. It is these that will have to be watched for and checked in time if the development of a new cycle of locust infestation is to be prevented.

In Fig. 23, an attempt has been made to indicate the location of the main rek-areas along the coast as well as in the interior of Mekran, and of all probable centres of outbreaks in the Mekran area. From the data available, it does not appear that the rek areas are important from the point of view of causing outbreaks. When good rains are received, general breeding may occur leading to an increase of population, but the actual outbreak centres have, so far as known always come into existence mostly in or near patches of summer or late spring cultivation in the interior of Mekran. Incipient swarming occurred in the Dasht valley (Pl. 39) in 1911 (and possibly in 1923), in Kulanch in 1926 and in Kech and Panjgur valleys in 1935 [Rao, 1933, 1936]. In all these cases it was associated with jowar cultivation. In 1936 an outbreak centre of small magnitude occurred in Kolwa also in cultivated fields, and in 1937 a similar one was detected near Sheh Lakhra (*vide* Pl. 40) in the Porali valley in Lasbela. Concentrated breeding was noticed in 1937 also among cultivation in Kachhi and in the Bolan and Harnai valleys. Jhalawan was not visited after 1932, but this area is probably of as much importance as the Kachhi and Bolan (*vide* Pl. 19) areas from the point of view of locust breeding, as it is a well-cultivated area. It would be necessary to examine the various valleys, such as that of the Mula, to find if conditions there would favour the formation of incipient swarms.

Conditions are rather different in the Sind-Rajputana desert areas. They form an immense region of sand-dune country covering thousands of square miles, which is covered after the rains with dense ephemeral plant growth that usually dries up at the end of the monsoon.

The permanent vegetation consists of tall bush which does not afford any shelter to locusts during the dry season, the ground being almost bare then, so that very few are to be seen in the desert at this time. With the outbreak of the monsoon, however, the ground becomes so thickly, covered with grasses and other annuals, that the locust migrants, on arrival become virtually scattered among the surface vegetation all over the desert, so that there is generally little possibility of the hoppers produced here becoming crowded. On the other hand, there are greater chances of concentrations forming in years of low rainfall, for then the vegetation is sparse in most places, and the adult locusts tend to concentrate in the few areas where stray rainfall has occurred and comparatively abundant plant-growth is seen. Similarly, at the tail end of the monsoon, the vegetation generally begins to dry up unequally and there are greater chances of hoppers getting concentrated in the few green patches seen in the midst of dried-up herbage. At certain times, however, as already mentioned elsewhere, the winds accompanying depressions have the effect of conveying locusts to centres of rainfall and thus bringing about crowded breeding. Even in the desert, hoppers are mostly noticed in the vicinity of patches of cultivation (mostly *bajri* and *guar*), which are generally to be found in hollows between the dunes.

Under ordinary conditions there are greater chances of locusts of the *gregarious* phase reverting to the *solitary* in the desert areas than of the reverse happening, and gregarious locusts do not retain their swarm character unless the swarms are large. There does not seem to be much likelihood of a transformation of the phase *solitaria* into phase *gregaria* except when the vegetation is patchy either on account of scanty and scattered falls, or due to the drying up of vegetation at the end of the breeding season.

On the whole, the desert region requires further examination for obtaining precise information in respect of the existence and distribution of outbreak centres in this extensive area so as to enable the locust organization to keep watch over them.

(The surveys of the outbreak centres of Mekran were begun under the guidance of the writer in February, 1936, and were continued and completed in the course of two years by the exertions of Mr. Rashid Ahmad, Mekran Survey Assistant and Dr. M. L. Roonwal.)

CHAPTER IV

SOME CONTRIBUTIONS OF THE SCHEME TO A KNOWLEDGE OF LOCUSTS IN INDIA

PRIOR to the period of the present investigations, almost all recorded observations on the habits and life-history of the desert locust in India had reference to the *gregaria* phase, and even outside India, information on the *solitary* phase was very scanty, so that the work done under the Indian scheme on the habits and life-cycle of the *solitaria* locust had to break practically fresh ground. In the course of field observations and experiments over a series of years at various stations in the desert regions of north-western India, results have been obtained, some of which may be claimed to have contributed towards a definite advance in our knowledge of locusts in general in India. Prominent among them are (1) evidence obtained in regard to the occurrence of seasonal migration of solitary locusts in the Indian area: (2) the delimitation of the area of habitat of the solitary locust: (3) a change in the conception of the origin of outbreaks: (4) the location of probable out-break centres in the Mekran area: (5) the importance of quality of food in accelerating sex-maturity and hopper growth: (6) the correlation of the number of eye-stripes and antennal segments with the number of hopper moults, etc.

Of the above, the evidence gathered in regard to *solitaria* migration, and the results obtained in respect of the mapping of possible outbreak centres in Mekran has already been dealt with in the preceding chapters. It is proposed now to make a few remarks on some of the other contributions.

1. *A Change in the Conception of the Origin of Outbreaks*

As already shown, locust infestations have been tending to appear in India in fairly periodical cycles. The unexpectedness of their visitations and the trail of havoc left in their wake have often over-awed the superstitious into considering them as manifestations of Divine Anger. Even the most enlightened could not penetrate the mystery of their sudden apparition, nor offer an explanation as to how they originated. It was, however, generally believed that they came from a western direction, possibly from Persia or Arabia, and that after an activity lasting two or more years within Indian limits they died down here. Cotes [1891] was of opinion that the breeding grounds of the locust were partly in the sand-hills of Rajputana and partly in the country beyond the Sulaiman range, while Webb-Ware [1915] considered that the Dasht-i-Lut or the Great Kirman desert of Persia was the main source of the spring infestations in Baluchistan and that the summer breeding in Rajputana was derived from the spring breeding in the latter country. It was however, obvious that none had any idea as to what was happening to locusts during the intervals when swarms were not noticeable, or how new locust outbreaks were produced.

It was not till 1921, when Uvarov [1921] on the basis of his field studies of the Asiatic Locust—*Locusta migratoria migratoria* L. in south Russia, propounded his theory of the phases of locusts, that a rational explanation of the periodical visitations of locusts was obtainable. He showed that when gregarious swarms disappeared, the species did not die down, but only reverted to what may be called the 'solitary' phase which was to be found scattered in small numbers in the permanent breeding grounds of that particular locust. When, however, climatic conditions favourable for the multiplication of the locust were met with

once again, the insect gradually increased in numbers and appeared once more in the form of swarms of the gregarious phase. Although there was much opposition at the beginning, the idea of the occurrence of locusts in two distinct phase forms has been almost universally accepted, especially as it received strong support from the results of various workers, such as Faure [1928 & 1932] in South Africa, Zolotarevsky [1929, 1933] in Madagascar, and Johnston [1926] and Maxwell-Darling [1936], both of whom noted the transformation of phases in the desert locust on the Red Sea coast of Sudan in 1926 and 1934-35 respectively.

At the period, therefore, when the present investigations were commenced—1931-1932, the general view as to how locust cycles recurred periodically was somewhat as follows. With the breakdown of an infestation, the swarms would diminish in number and size and ultimately disappear, and simultaneously, the area of their distribution would become narrowed down to the limits of their permanent breeding grounds where they would be found in the form of scattered individuals of the solitary phase. If, in the course of time, favourable weather conditions, such as heavy rainfall, should occur, intensive breeding would be induced and lead to the building up of a large population during one or two successive seasons. Sooner or later, swarms of the *gregaria* phase would be formed and invasions of large areas of surrounding country would follow. In fact, Khan Bahadur Afzal Husain concisely defined the conception of locust cycles prevalent at the time [Husain, 1933] thus: "During the periods of lull, the locusts survive in their permanent breeding grounds, greatly thinned in numbers. When their numbers have increased and they have acquired sufficient density of population, they migrate in thick swarms and invade territories hundreds of miles off."

In the course of intensive survey work carried out in various parts of the locust habitat during the period 1931-1939, it became obvious that the conception of locust developments outlined above might need a great deal of revision, in view of the greater insight obtained into the habits and activities of the solitary phase of the locust. The results of surveys have indicated that the population found in the breeding grounds is rarely of a static character, but is, on the other hand, marked by a remarkable degree of fluctuation in density, which is affected at times by a rise due to local breeding, and at others by an immigration or emigration of individuals. Only small numbers of locusts have, in general, been noticeable in these places during the dry season, whereas, in years of complete drought none at all can be found there. Secondly, *solitaria* individuals have been found capable of migrating long distances, so that those bred in winter-rain areas are able to reach regions of summer rainfall and *vice-versa*, at the change of the seasons, for breeding. Thirdly, phase transformation has been found to occur, not in what have been called the permanent breeding grounds, but in certain ecologically peculiar locations—the outbreak centres—often situated far from them.

It is thus seen that the earlier views in regard to the starting of a new cycle of infestation may have to be profoundly modified. Although during years in which swarms are absent the distribution of the locust is limited to certain ecologically favourable areas, such as the 'reks' of the Mekran coast or the 'desert' areas of Rajputana, which may be termed its breeding grounds, it is not able to live and breed exclusively in them throughout the year, as the rainfall period is confined only to the winter or summer months, and the rest of the year is more or less dry. By its ability to make long-distance migrations, the solitary locust is apparently able to have two broods in the year, the first one in spring in the western

winter rain areas and the second one in summer in the eastern or 'desert' areas. The circumstance that the locust has normally two broods in the year, occurring in two distant breeding grounds situated in different seasonal rain-belts, should always be taken into account in making a study of the origin of locust outbreaks. Secondly, the production of swarms is brought about not as a direct result of extensive multiplication in their breeding grounds or areas of habitat, but as the outcome of concentrated breeding in localities with the requisite ecological conditions, which may be termed its 'out-break centres'. The optimum conditions for the building up of swarms would occur, when the adults of the first generation of the season, produced extensively in the general breeding grounds, become concentrated in the outbreak centres by the action of various factors and are forced to lay eggs in restricted areas. As a result of the crowded breeding that follows, incipient swarming is brought about involving a transformation of phase. Good rainfall in the latter part of the normal rainy season is a factor of much importance in the development of out-break centres, since a large increase of populations is possible only if a second generation rapidly follows in the wake of the first brood.

2. *A change in the conception of "Breeding Grounds" of the Solitary Phase Locust in India*

During the earlier years of the infestation, only those areas in which solitary locusts were noticeable and especially those in which green-coloured hoppers were found to occur were considered to be the permanent breeding grounds of the solitary phase. The 'rek' areas of the Mekran and Lasbela coast were some of the earliest ones discovered, and subsequently solitary locusts as well as green hoppers were found also in many parts of the Rajputana desert areas. In the course of further work, it was noticed that in the western areas, such as Gwadar, Pasni and Ormara, breeding occurred mostly in the spring months in the wake of winter rainfall, whereas in the summer months there was rarely any breeding and comparatively few adult locusts were to be seen. On the other hand, in the desert areas of Sind and Rajputana, few locusts were to be found in the winter and spring months in general, though with the commencement of the monsoon, good numbers of locusts were observable, as also numerous green hoppers, in areas of good rainfall.

In years in which rainfall was low or scanty, whether in the summer or winter rain areas, breeding might be completely absent and even adults might be scarce, whereas heavy breeding would occur in the wake of good rainfall.

In addition to the 'rek' and 'desert' areas, breeding was noticed at various times in certain inland areas in western Sind, in Kachhi, in the Bolan valley and in the Dera Ghazikhan area whenever good spring or summer rainfall had been received.

The experience gained since 1935 has shown that the locust population produced in spring in the western winter rainfall areas usually migrates eastwards at the beginning of summer into the summer rainfall areas of the Indian desert and that the new brood in the latter areas usually finds its way mostly into the western winter rain areas by the end of the autumn or during the winter. In these circumstances, therefore, one cannot consider either the western 'rek' areas alone or the eastern desert areas by themselves as the sole breeding grounds of the desert locust. In fact, the winter breeding grounds form the complement of the summer brood areas, and *vice versa*. The whole area of habitat, including the greater part of Mekran, the Kachhi-Bolan areas, parts of southern Iran, parts of eastern Arabia and the desert areas of Sind, Rajputana and

southern Punjab, should be deemed to be a complex of outbreak centres composed partly of winter-rain areas producing a spring generation, and partly of summer-rain areas producing a summer and sometimes also an autumn generation, connected with one another by a migration of populations at the change of the seasons.

Kennedy [1939—p. 459] working on the Sudanese coast of the Red Sea came to somewhat similar conclusions. He states: 'I suggest that this coast is part of a complex of centres, and the rest may be in the Eritraean or Sudanese hills, still uninvestigated, or the Arabian Coast of the Red Sea [Maxwell-Darling, 1937], just as the coastal and inland areas of Mekran are complementary centres for Indian out-breaks, and coastal and inland areas possibly complementary in Mauretania.'

3. *Some General Results of the Investigations*

The field observations made in the course of the progress of the scheme have made it abundantly clear that the main factor on which the life-economy of the locust is pivoted is *rainfall*. In the desert and semi-desert country which mainly forms the habitat of the locust, the conditions of the environment are absolutely dependent on the occurrence of rain. All the requirements of the locust are met if there is good rainfall: vegetation to serve as food and shelter, optimum conditions of atmospheric temperature and humidity and the requisite degree of soil-moisture for oviposition. When there is a failure of rainfall, the general conditions are so adverse that the locust usually flees from such areas.

Some of the ecological observations made would appear to indicate the importance of *soil-moisture* for the well-being of the locust, not only from the point of view of egg-laying, but also from that of providing the requisite conditions of living for the adult locust. Observations under the conditions noted at Pasni showed that the main factor concerned in causing locusts to leave the Pasni area, in spite of the presence of high air humidity, was the lack of humidity at the soil surface—due ultimately to a lack of moisture in the soil.

Another important fact that has been disclosed during survey work is the part played by *storms*—whether rain or dust-storms in transporting locusts from one area to another, and very often conveying them to actual places of rainfall.

Our feeding experiments have shown that the adult locusts have a *preference for cereal crops* like jowar, bajri and maize, and also that females fed on jowar and maize matured earlier and laid a larger number of eggs. Since most of the outbreak centres noted in Mekran were always associated with the jowar crop, there is little doubt that, besides the visual attraction to tall crops on the part of locusts—emphasized by Kennedy [1939], the food value of the plants may also not be a negligible factor.

The role of light or sandy *loam* soils in incipient swarming would appear to be an important point. In sand-soils, the moisture dries up within 4 to 6 weeks of a good fall, whereas loam soils are more retentive, and there is the further consideration that such soils may receive irrigation if crops are grown on them. There are thus greater chances of breeding continuing on loamy soils than on mere sand.

The correlation of the number of eye-stripes and antennal joints with that of larval moults is a very interesting contribution to a study of the intricacies of the phase problem, though not of importance from the point of view of locust control.

PART II

STUDIES ON THE ACTIVITIES AND DISTRIBUTION OF THE SWARMS OF THE DESERT LOCUST (*SCHISTOCERCA GREGARIA* FORSK.) DURING THE PAST CYCLES OF MASS-MULTIPLICATION IN INDIA.

INTRODUCTORY

ONE of the objects of the Locust Research Scheme that was in progress during the years 1931—1939 in North-west India, under the auspices of the Indian Council of Agricultural Research in India, was the collection of all available information on the past infestations of locusts in India and a study of the data collected in correlation with meteorological factors. Although it was generally recognised that locust invasions usually came from a western direction from sources beyond the borders of India, and also as a rule pursued a west-to-east direction, there was no definite information as to the routes usually followed by migrating swarms in India, nor any as to how their flights were affected by changes in the weather. Beyond a general impression that adult locusts of a new generation produced in an area of intensive breeding ultimately departed from that region towards some other distant area, there were no definite ideas as to the existence of any connection—direct or indirect—between the occurrence of spring or summer breeding in parts of Baluchistan and north-west India and the dense flights that in some years reached as far as Assam in the east, and as far as Madras in the south. A sound knowledge of the factors affecting the movements of locust swarms in the different parts of India would obviously be invaluable for enabling the Central Government to warn provinces liable to such invasions before-hand so that they might equip themselves, in good time, with the necessary organisation and material for the prevention or control of likely attacks.

SOURCES OF INFORMATION

As is, indeed, well known, the conclusions arrived at from an examination of any set of data are less likely to be faulty or inaccurate, the greater the volume of information available for study. It was only since February 1930, following the establishment of the Locust Bureau of the Indian Council of Agricultural Research, that a system of centralised locust intelligence was brought into being at New Delhi for the receipt of information on the movements of locust swarms in or outside India, and for the prompt despatch of warnings to all provinces subject to locust invasions. Consequently it is only for the years 1930 and 1931 that fairly complete information has been available for purposes of study in the case of the last locust cycle—1926—31. Data for years prior to 1930, had, therefore, to be collected by a perusal of all available records on locusts in the various provinces of India that had suffered from locust infestations in the past. Much information was also gathered by a study of records of locust damage generally included in the weekly season and crop reports published in official gazettes, such as the "Gazette of India" and the gazettes of various provinces. In the case of Baluchistan, the Political Diaries of Baluchistan Agency from 1901 to 1930 were kindly loaned to the writer for the extraction of notes on locust incidence and proved to be a mine of valuable information in regard to Baluchistan. In addition, various Gazetteers, including the Imperial Gazetteer of India, and the Gazetteers of various Indian Provinces and States were perused as far as possible for information on past locust visitations, so that, by the close of the Locust Research Scheme in 1939, a great mass of fairly detailed data on locusts had been collected, dating from the year 1862, and in addition, also some scraps of information for some of the earlier years of the 19th century.

The following were some of the main sources, from which data on locusts forming the subject-matter of the present studies, have been extracted.

1. The periodical communications on locusts issued by the Locust Bureau of the Indian Council of Agricultural Research from February 1930 to 1939.

2. Files on Locust Control belonging to the Revenue Departments of various provinces and States in India, *viz.*, Punjab, Sind, United Provinces, N. W. Frontier Province, Baluchistan Agency, Rajputana Agency, Western India States Agency, Kalat and Lasbela States, Jodhpur, Jaisalmer, Bikaner and Sirohi States, Central India States (Gwalior, Indore) and Punjab States (Patiala, Jind, Bahawalpur, Nabha etc.).

3. Locust files of the Agricultural Departments of the following provinces:

Punjab, United Provinces, Sind and North West Frontier Province.

4. Locust Files of the Imperial Entomologist, Pusa; the Government Entomologist, Punjab; and the Government Entomologist, United Provinces.

5. Administration reports of the Baluchistan Agency from 1885 to 1930; Diaries of the Baluchistan Agency from 1900 to 1930.

6. Reports of the Political Administration of the Rajputana Agency from 1866 onwards.

7. Annual Administration Reports of the Department of Agriculture (or Department of Agriculture and Land Records) from 1880 to 1931, as far as available: Bombay, Madras, Bihar and Orissa, Bengal, Assam, Hyderabad State and Mysore State.

8. Weekly Season and Crop Reports published in various Official Gazettes; Fort St. George Gazette, United Provinces Gazette, Central Provinces Gazette, Bihar and Orissa Gazette, Bombay Gazette, Assam Gazette etc.

9. Chapters on "Famine" and "Locusts" in various Gazetteers: Imperial Gazetteer of India, District Gazetteers of various Provinces: Bombay, Sind, Madras, Mysore, Baluchistan etc.

10. Cotes' Report on "The Locust of North-western India" [1890].

11. *Indian Museum Notes* (Old Series) 1888 to 1900.

12. Predtechensky's *"Annual Cycle of the Desert Locust in Persia and adjacent countries of Tropical and sub-tropical Asia'*—[1935].

14. Uvarov's *"Surveys of Locust Outbreak in Africa and Western Asia"* in 1925—31, 1932, 1933 and 1934.

15. *"Surveys of Locust Outbreak in Africa and Western Asia"* in 1935, 1936 and 1937 by Uvarov and Milnthorpe.

16. Note on *"Locust attack of* 1926-27 *in Sindh, Kathiawar and Gujarat"* by H. H. Mann and W. Burns [1927].

17. Note on *"Locusts in India"* by T. B. Fletcher [1931].

18. Note on *"Locust Problem in India"* by P. B. Richards [1931].

19. Note on *"The Desert Locust in the Punjab"* by M. Afzal Husain [1931].

20. *"An account of the Locust visitations in India during the last cycle*—1926—1931"—(Indian Journal of Entomology) by M. Afzal Husain [1942].

NATURE OF THE DATA COLLECTED

Though, on the whole, most of the data collected satisfy all the necessary requirements in respect of our present studies, there is little doubt that some of them do not come up to the mark. In certain cases, one is in doubt as to whether the report in question refers at all to the Desert Locust. In Kachhi, the Black-headed cricket is a serious pest of the Kharif crops and as it is known there as '*Tid*', it is often liable to be confused in the reports with the desert locust which is known as "*Tiddi*", though in view of the cricket being mostly noctural in habits, one can generally, decide which insect is under reference. Again, in the Bombay Presidency, which is subject also to the incidence of the Bombay Locust it is not easy to decide off-hand to which species a particular report is referable. In 1878, when *Locusta migratoria* was active in Madras, it was found that swarms of the Desert Locust also reached the northern districts of Madras in the cold weather, and in the Nellore district where *Locusta* was known to have been present in July-August, but to have disappeared by September, the reports of flights in November were at first supposed to denote a reappearance of *Locusta*, until this was corrected by a closer study of the movements of *Schistocerea* during the autumn months of 1878 in Bombay, Hyderabad and Madras.

In some cases *hoppers* are referred to as "young locusts", while in other cases, recently fledged adults are also called "young locusts". This often causes some confusion. In many of the reports, the colour of the locusts is not mentioned so that one is left in doubt in regard to the age and the state of maturity of the swarms.

In the case of information extracted from some of the administration reports for past years, often only general statements are found to have been made as to the appearance of swarms without specifying the month or the season of their visit. In the case of Bihar and Bengal, one is unable to say, without reference to other corroborating evidence, whether swarms had appeared at the beginning of summer (June-July) or in autumn (October-November). In regard to data extracted for some of the early years of the 19th century from some of the Gazetteers, bald statements, such as locusts appeared in Jhalawar in 1812, occur, the full significance of which can be realised only when examined in the light of the result of the studies of locust movements of the recent locust cycles. Another point in regard to which inaccuracy is likely to creep in is the direction of flight. Swarms in flight are likely to be influenced by various factors such as the velocity and direction of the prevailing winds, the attraction of vegetation, the time of day, and local temperatures. During the prevalence of dust or thunder storms, the direction of the winds is likely to vary greatly and there are thus many chances for the occurrence of mistakes in adjudging the direction of flight at such periods.

However, any such small inaccuracies will apparently not matter much, as the real direction of migration of swarms as a whole will be apparent only when the progress of the movements is carefully followed on a map. As Pasquier says: "The direction of flights noted is valid only for the particular time of the observation, being always the function of the terrain, of the season and of the time of the day. It is from the orientation, on the chart, of regions successively reached that one can infer the general direction of the invasion, and not from statistical calculations worked out on the basis of the directions indicated in the case of various reported flights." [Pasquier 1942].

In regard to the reliability of many of the locust flight reports, it may be stated that most of the reports issued by the Provincial Administrations are based on the information furnished by village Headmen, as under

the ordinary system of Revenue Administrations in India, the onus of reporting the occurrence of locust damage or breeding falls on these village officers. These reports may not of course be first-hand information based on personal observations, but on a foundation of mere hearsay or on complaints made by cultivators, and thus may include various inaccuracies of detail. In most cases, however, there is little doubt that such locust intelligence is not to be treated as spurious but as being concerned with real facts, especially in those cases where actual damage to crops is mentioned. Reports of crop damage by locusts included in the season and crop reports of past years should, therefore, be considered to be positive information of a valuable character.

General Methods of Study

All the data collected during the period 1931 to 1938, were typed serially in a tabular form indicating the source of information, the date of occurrence, the province and district affected and the subject matter of the report briefly extracted. These data were then classified under different provinces for each year, and typed after arranging them in chronological sequence in respect of the data of occurrence. The greater part of the data, thus arranged up to the year 1939, was checked and edited as far as possible and published in 3 volumes: Vol. I: containing data for 1926—1931 for the desert areas of N.W. India (Sind, Baluchistan Rajputana and Western India State); Vol. II: containing data for 1926—1931 for the cultivated plains areas: (Punjab, United Provinces, N. W. Frontier Provinces, Central Provinces, Central India, Bihar and Bengal); and Vol. III for years prior to 1926 (1803—1925), for the whole of India. Only a limited number of copies were, however, printed, which were distributed to the Governments of various provinces in India and to such entomologists in India as were interested in locusts and to the International Anti-Locust Research Centre, London.

It was, however, found, when the printed data were subjected to a detailed analysis by the writer that many mistakes had crept into the printed text, which had first to be corrected by checking up with the original files or notes as far as feasible. Moreover, data regarding many of the provinces as for instance, United Provinces, Central Provinces, Bihar, Bengal, and Madras and Hyderabad State, had not been gathered for a great many of the past years (especially 1874—1919). The provinces concerned were, therefore, addressed by the Imperial Council of Agricultural Research for supplying information direct to the writer for filling up the obvious blanks. The response obtained was, on the whole, rather feeble, but fortunately as the result of facilities kindly provided by the Mysore Government Secretariat for examining the old volumes of the Gazette of India, the Mysore Gazette, and the Fort St. George Gazette, at Bangalore, the writer was able to extract valuable information for most of the years in question from the data on locusts included in the weekly season and crop reports. Further information was also extracted from the Gazettes of the Central Provinces, the United Provinces etc., at the Imperial Records Library at Delhi. The additional information thus obtained was added to the printed data under the appropriate years and areas. The whole mass of information thus gathered was analysed and arranged under the different seasons and correlated as far as possible with available meteorological data, and also with such data as were obtainable in regard to locust activities in areas outside Indian limits.

Mapping. The data on the movements and breeding of locust swarms were plotted out on skeleton maps of India, month by month, using the internationally recognised signs for purposes of study, in correlation with meteorological data. During periods when the items to be included in

the map in any particular month were so numerous as to make the plottings too crowded and confused, the locust situation was shown fortnight by fortnight or at times even week by week. Such maps were prepared as far as possible in triplicate for purposes of record and study.

In addition, maps showing the situation in regard to locusts during the earlier and the latter halves of the year were prepared for some of the important years, and ultimately, also annual maps showing at a glance the areas of over-wintering, and of spring and summer breeding, as well as the direction and extent of the summer and autumn flights during each particular year.

In preparing these maps, the actual reported direction of individual flights on particular dates has been shown only when there were few swarm reports. In cases where numerous flights had been reported, the arrow marks on the maps are indicative of the general direction of movements of locusts *en masse* at that period.

In tracing the advance of swarm movements, it has often been found that, while information as to the presence of flights in areas far off is available, there are no records of their movements over large tracts of intervening territory. For instance, while reports are on record regarding flights over the eastern parts of the Punjab and parts of Rajasthan, and also over parts of Bihar and Bengal, there is no information in some years for large intervening areas such as the United Provinces and the States of Central India. Similarly, there is recorded information in certain years regarding flights in a southward direction in parts of the Central Provinces, and later on regarding swarm movements in the northern parts of Madras or in the eastern districts of Bombay, and though there are no actual records of flights, there is little doubt that these swarms had actually traversed Hyderabad territory. As regards a study of the progress of individual swarms, it is almost impossible from the available data on flights (however accurate the reports may be) to trace their actual movements. This task can, apparently, be undertaken only if observers are set apart to follow the movements of swarms from place to place.

It is doubtful, however, if a swarm ever continues to have an organic individuality of its own for any considerable period of time. It has often been observed that while the main body of the swarm is moving on, large groups of individuals may cut adrift from it and alight on the ground for purposes of feeding or resting. In other cases, the swarm may, on meeting resistance to its movement in the shape of a mountain mass, [Predtechensky 1935], or adverse winds, may break into smaller swarms, each of which may pursue its own direction of flight. At times, individuals from disintegrated swarms may become re-united under favourable weather conditions to form small groups, and small swarms may unite to form larger flights under similar conditions.

Effect of Climatic Conditions on Locust Economy: Correlation with meteorological data

Among the environmental factors by which the life of the *gregaria* phase of the locust is affected in its natural habitat, the most powerful is that of the climate. When climatic conditions are favourable, it has vegetation in abundance for food and shelter, and has the requisite soil moisture for oviposition and multiplication. Its biotic potential is high enough to withstand the inroads made by its natural enemies. On the other hand, when climatic conditions are adverse, it does not have sufficient food and is unable to breed, so that there is a rapid decline in its numbers leading to the disappearance of swarms.

Among the climatic factors by which locust swarms are affected, the important ones are:—1. Temperature, 2. Humidity, 3. Rainfall and 4. Wind currents.

In north-west India, the general atmospheric *temperatures* are usually not adverse to locust activity except in the winter months. In summer, though the day temperatures may soar high in the desert areas, locusts do not seem to mind them if the atmospheric *humidity* is not too low. When the humidity is low, adult locusts would appear to leave such areas and fly elsewhere. In the dry areas in which locusts have their natural habitat, the main pivot on which locust economy would appear to be hinged is rainfall. When there is sufficient rainfall, the soil gets the requisite amount of soil moisture for oviposition and breeding, the general temperature is lowered sufficiently, and plenty of vegetation springs up in the desert, so that all the other factors are really dependent on rainfall.

Another factor which has a profound influence on locust activities is the nature of the prevailing winds. When the winds are dry, the soil moisture is rapidly sucked up and the vegetation dries up, and under such conditions, swarms quit the area by taking to flight. When in the air, the direction of their movements would naturally be influenced by that of the prevalent winds. Flights are also greatly influenced by the prevailing air temperatures. In cold weather, locusts remain on the ground or on vegetation resting in an inactive condition until they become sufficiently warmed up by sun's rays. Flights do not usually begin until the air temperature rises to at least 70°F, and are never observed during the prevalence of chill winds. In cold weather, locusts fly only during the afternoons, if the weather is warm enough, but in the hot season, flights may continue during nights long after sunset.

In these circumstances, therefore, the main points on which correlation is sought between the recorded information on locust activities in past years and the meteorological data recorded in the Indian Daily Weather Reports is (1) Rainfall and (2) Direction of wind.

Rainfall. Most of the activities of locusts lead to and culminate in breeding, for in the absence of reproduction, there is the danger of the extinction of the whole race of locusts. The life of one generation virtually comes to an end when it has finished egg-laying, and a new generation comes into being when hoppers hatch out. Breeding is entirely dependent in nature on the occurrence of sufficient and timely rainfall. It is only when a heavy fall or over an inch of rain occurs that sandy soils become sufficiently wet to allow of eggs being laid by parent locusts. If instead of one drenching downpour falling on the particular day, the same amount of rain is spread over 3 or 4 days, the effect would not be the same, as the moisture would not then penetrate sufficiently deep into the soil.

Usually rainfall of various stations is recorded as monthly and annual totals. Though the figures of monthly totals generally suffice to indicate whether the requisite quantity of rainfall had occurred, it is difficult to say how much of the amount shown could be classed as effective rainfall and how much of it is made up of small ineffective falls spread over a number of days. Sometimes rainfall might have begun at the end of a month and have continued into the early part of the month succeeding. Though a fairly good total amount of effective rain might have fallen during a continuous period, yet, as shown in the monthly records, the rainfall figures might not be useful for purpose of correlation.

Heavy rainfall exceeding certain limits would appear to be prejudicial to locust breeding. In many cases, the soil moisture would be so high as to cause the eggs laid in the soil to rot, and in other cases the soil would be too sodden to permit of eggs being laid at all. Heavy downpours may kill or wash out the young hoppers and high atmospheric humidity would, moreover, be favourable for fungus attack on adults and hoppers.

On the whole, however, the monthly totals have proved for all practical purposes quite useful for purposes of correlation.

Wind Direction. Though in general experience, flights of locusts are governed by the direction of the prevailing winds, it is only in rare cases that wind direction is also indicated in the body of reports on locust visitations. As the direction of wind movements is included in the synoptic charts for a great many stations in India, attempts have been made to correlate the direction of locust flights with those recorded for particular stations in the same area. It is, however, to be noted that locust flights more often occur in the afternoons, whereas till about ten years ago, it was only the 8 A.M. observations on wind directions that were included in the Daily Weather Reports. It is, however, well known that the direction of winds in the afternoons is very often different from that of the morning winds, except during the height of the monsoon, when the direction is steady for the whole of the day. In certain parts of the year, dust or thunder storms may develop in the afternoons and may be accompanied by strong winds, so that a correlation of the direction of locust flights is not possible in such cases in the absence of information regarding the afternoon wind directions.

A study of the movements of cyclonic storms or of depressions, as depicted in the Daily Weather Charts, has, however, given very valuable clues in regard to an explanation of the extraordinary directions taken by locust swarms in particular years. In 1901, for instance, summer flights passed from Central India and Central Provinces southwards into Hyderabad and Madras up to the middle of June, but after this time, they took an easterly direction towards Bihar and Bengal,—movements, which show an obvious correlation with the dates of developments of northerly, and westerly winds, respectively, in connection with the formation of certain depressions and storms in the Bay of Bengal.

SECTION VII.—THE PERIOD—1920 TO 1939

CHAPTER I

LOCUST INFESTATION CYCLE OF 1926—1932 IN INDIA

Sub-period 1926—1928

THE cycle prior to the 1926—1932 period of infestation in India began in 1912 and lasted till 1919. From the data available, no swarm movements of appreciable importance were reported in India from July 1919 up to August 1926 and in spite of the fact that gregarious breeding is recorded to have occurred in the spring of 1922 in Kachhi, in April, May and June, 1923 in the Dasht Valley of Mekran and again in the spring months of 1924 in Kachhi, the period of six years from 1920 to 1925 should, on the whole, be considered to be a swarmless interval, strictly comparable to the recent period of 1932—1939, during which the solitary phase of the Desert Locust was under special study in North-West India. It would appear to be advisable to review the available data for this swarmless period (1920—1925) in the light of the results of the detailed observations made during 1932—1939, and it is proposed, therefore, to postpone a discussion of the data to a later stage.

THE LOCUST CYCLE—1926 TO 1932

After a period of six years of absence of infestation during which no locust swarms were reported in India proper, flights appeared rather all on a sudden, in various places in Sind and Lasbela in August-September 1926. As a result of breeding, large fights of pink locusts developed in Sind and Rajputana and invaded Kathiawar, Gujarat, Baluchistan and the Punjab during autumn and winter. After passing the winter months of December, 1926 and January 1927 in a comparatively inactive condition in the Punjab, Sind and Baluchistan, the swarms became active again in February and laid eggs in Baluchistan and the Punjab, and thus started the new infestation cycle in India.

The Origin of the 1926 swarms in Sind

Locusts do not usually attract notice unless they appear in spectacular numbers and until the outbreak attains serious dimensions, so that the initial stages in the development of the outbreak, when naturally the pest would be present only in small numbers, would be over-looked by most people. The task of detecting the initial immigrants, or of keeping a watch over the development of incipient swarms, would necessitate the employment of a special staff of observers capable of noting local rises of population among locusts of the non-gregarious type in the outbreak areas.

Under these circumstances, only scanty data have been available in regard to the period prior to August, 1926, and it, therefore, follows that only surmises are possible in any attempts at determining the mode of origin of the initial swarms of 1926. The information on hand is duly detailed below and will be discussed in correlation with available meteorological data.

YEAR 1926

A. Weather Data—1926

I. *Winter-Spring Rainfall*—1925-26:

1925-1926	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Iran								
Bushire	2·06	3·19	..	2·81	1·82	1·32	..	..
Jask	1·87	..	..	5·14	0·43	0·72	0·08	..
Seistan	0·62	..	0·04	1·16	0·19	0·65	0·10	0·27
Arabia								
Muscat	1·75	0·05	..	0·98	..	0·34	0·38	..
Baluchistan								
Pasni	0·03	..	..	7·37	0·21	0·48	..	..
Panjgur	..	..	..	3·69	0·04	1·38	0·05	0·62
Turbat	..	0·04	0·07	7·83	0·31	1·84	..	0·49
Ormara	..	..	..	13·80	..	..	..	..
Bela	..	0·66	..	1·87	..	0·63	..	2·07
Quetta	0·38	0·07	0·12	1·78	1·78	3·09	0·73	1·63
Nushki	0·10	..	0·15	2·39	0·68	0·72	3·63	0·05
Mithri	0·01	..	..	0·40	..	1·12	..	..
Sind								
Karachi	..	0·25	..	0·24	..	0·88	..	..

Western disturbances commenced early in October 1925 and gave good falls in Bushire (2·06″) and Jask (1·87″) in Persia, and in Muscat (1·75″) and in parts of Upper Baluchistan. There was little rainfall in November and December, but in January 1926, heavy rains were received in Persian and British Mekran about the middle of the month, with the intensification of a disturbance into a depression over Mekran, the total for January being: Jask 5·14″; Pasni 7·37″; Ormara, 13·80″; Panjgur, 3·68″; Turbat, 7·89″; and Bela, 1·87″. Some further rainfall was received in March, in Mekran and Upper Baluchistan, especially on the 12th. Panjgur receiving 1·38″ and Turbat 1·84″, Mand 2·71″ and Pasni ½″. Some light rainfall was also received in May in the interior of Mekran: Turbat, 0·49″; Panjgur 0·62″ and Mand 0·81″.

II. *Monsoon Rainfall* 1926: (*Monthly Rainfall in inches*)

1926	May	June	July	Aug.	Sept.
Baluchistan					
Mithri	..	..	1·74	3·70	0·20
Sonmiani	..	..	..	0·40	5·30
Bela	2·07	0·54	0·58	0·55	2·79

1926	May	June	July	August	September
Sind					
Karachi	..	..	0·68	2·40	**13·95**
Jacobabad	0·95	..	0·93	1·09	**0·06**
Nagar Parkar	0·22	0·05	3·71	13·55	**16·07**
Mithi	1·61	..	9·44	6·73	**10·06**
Chachro	2·13	..	2·25	7·91	**3·52**
Umarkot	1·7	..	2·40	6·15	**1·42**
Rajputana					
Barmer	1·11	..	3·51	4·17	**8·35**
Jodhpur	0·48	0·05	3·46	7·15	**7·16**
Phalodi	0·22	..	1·08	5·55	**0·80**
Desuri	0·72	0·47	4·28	10·72	**24·29**
Jaisalmer	1·32	..	2·52	6·25	**2·30**
Devikot	..	..	0·40	9·93	**3·27**
Bap	..	..	0·80	3·95	**0·30**
Bikaner	0·91	..	4·85	4·50	**1·31**
Nohar	1·44	0·23	5·87	2·38	..

There was light rainfall in many parts of the desert during May, but June was practically dry, the Bay monsoon reaching North West India only by the end of June. In July, four depressions appeared from the direction of the Bay of Bengal, of which the 2nd and the 4th reached Gujarat, Rajputana and Sind and gave a fair amount of rainfall.

In August, there were three depressions, of which the first (2nd to 12th) entered Gujarat on the 9th and gave good rainfall in Rajputana, and South Baluchistan. The 2nd depression (13th to 22nd) was active in Rajputana (Bikaner and Marwar), Sind and south Punjab, and the third gave good rainfall also in the same area.

In September, the first depression was active from the 30th August to the 6th September in Gujarat, Rajputana and south Sind and passed into the Arabian Sea after giving heavy rainfall in Sind (Karachi, 14 in. on 5-6 IX), and in Lasbela. The second depression (4-18 IX) affected Rajputana and Upper Sind, and also gave good precipitation. The monsoon withdrew from North-West India at the end of September.

B. Locust Data, 1926 (Vide Pl. 42, Fig. 1)

I. *Period from January to June, 1926*

The earliest record of the occurrence of locusts in Mekran relates to the third week of June 1926, when large numbers of locusts were said to have been damaging crops in Kulanch. Personal enquiries, however, elicited the information that, earlier in the season (during March-April), presumably as a result of heavy rainfall in January all over Kulanch and other parts of Mekran, fairly large numbers of hoppers (presumably of the *solitaria* or *transiens* type) had been noticed by the Pasni Niabat staff at various places in Kulanch: Nokbur, Gano, Kandiri, Nalent, Kandasole and Kappar, [Rao, 1933]. The likelihood of such an occurrence is borne out by the fact that in 1933 and 1935 large numbers of *solitaria* and *transiens* hoppers were, under more or less similar circumstances, found on the *reks* of the Mekran coast after heavy winter rainfall.

Text Figure 22—*contd.*]

(CONTINUED)

YEAR	SEASON	MEKRAN AREA	LASBELA AREA	SIND-RAJPUTANA AREA
1936	WINTER	(XII-II) 52 : 36 12 / 65 57 (INCLUDES INCURSION FORMS)	(XII-II) 52 40 8 / 57 43	OVER WINTERING IN THAR. (I-II) 86 11 3 / 81 59
	SPRING	MODERATE BREEDING. SPRING BROOD ON REKS (IV-V) 64 31 5 / 56 44		(FEW LOCUSTS)
	SUMMER	(INCURSION AFTER 27-V) 20 76 4 / 87 13	(V) 17 75 8 / 75 27	CHACHRO
		(VI-VIII) 52 44 4 / 62 58	(VI-VIII) 59 37 4 / 62 38	(VI) 35 6 4 / 77 23 (EARLY MIGRANTS)
			(LIGHT BREEDING)	DESERT AREA (VII) 70 25 7 / 79 21
	AUTUMN			EXTENSIVE BREEDING (VII-X) THAR MALLANI. NEW GENERATION
			(IX) 55 51 8 / 50 50	(VIII) 88 11 1 / 90 10 - FIRST BROOD NORTHERN AREAS
		(X-XI) 60 39 1 / 65 57	(X-XI) 67 30 3 / 65 55	LATE BROOD (X-XI) 72 27 1 / 48 52
1937	WINTER	(XII-II) 37 38 5 / 52 48	(XII-II) 64 33 1 / 84 58	NOKH (XII-II) 73 25 2 / 82 58 (OVER WINTERING)
	SPRING	NO BREEDING ON COAST. (LIGHT BREEDING IN INTERIOR) (IV-V) INTERIOR BROOD 78 19 3 / 68 32		(II-IV) LIGHT BREEDING IN NORTHERN DESERT
	SUMMER	(VI) MIGRANTS AT PASNI 71 29 0 / 51 49	SHEH LAKHRA OUTBREAK CENTRE (V-VI) 74 23 3 / 59 41	
		(VI-VIII) 67 26 1 / 77 23	(VI-VIII) 69 27 4 / 57 43	(VI) 85 15 2 / 71 29 (SUMMER MIGRANTS)
	AUTUMN			HEAVY BREEDING. I BROOD (VI-VIII) AND BROOD (IX-XI)
			(VIII-X) LIGHT BREEDING	(VIII) I BROOD 75 42 3 / 81 19
		(IX-XI) 34 41 5 / 76 24	(IX-XI) 53 45 2 / 72 28	(IX-XI) II BROOD 50 32 8 / 77 23
1938	WINTER	(XII-II) 38 58 4 / 65 37	(XII-II) 33 42 5 / 75 25	CHACHRO AREA (XII-III) 71 27 2 / 83 17 (OVER-WINTERING)
	SPRING	LIGHT BREEDING (III-V) INTERIOR NEW GENER 64 36 0 / 54 46	KACHHI - BOLAN (V) NEW GENERATION 56 41 3 / 74 26	
	SUMMER	(VI-VIII) 66 31 1 / 48 52 (INCLUDES SUMMER MIGRANTS)	(VI-VII) LIGHT POPULATION 78 21 1 / 50 50	(VI-VII) THE WHOLE AREA 85 15 0 / 60 40
				LIGHT SUMMER BREEDING (VII-X)
	AUTUMN			NEW GENERATION SOUTHERN DESERT 48 52 0 / 61 39 (IX-X)
		(IX-XI) 71 29 0 / 56 44	(IX-XI) 53 44 3 / 75 21	
1939	WINTER	?	(XII-II) 69 31 0 / 66 34	

EXPLANATION.—THE BIOMETRICAL FACIES OF THE LOCUST POPULATION OBSERVED IN THE AREAS CONCERNED HAVE BEEN BRIEFLY EXPRESSED BY THE NOTATION USED ABOVE, WHICH GIVES THE PROPORTIONS OF THE PHASES - SOLITARIA, TRANSIENS AND GREGARIA - IN PERCENTAGES OF THE TOTAL POPULATION EXAMINED IN THE NUMERATOR, AND THE PERCENTAGES OF FORMS WITH SIX EYE-STRIPES AND SEVEN EYE-STRIPES IN THE DENOMINATOR, AND THE MONTHS OF THE YEAR IN BRACKETS SHOWING THE PERIOD OF COLLECTION THUS,

(XII-II) 69 31 0 / 66 34 INDICATES THE FACIES 69 S 31 T : 0 G 66 (6) : 34 (7) COLLECTED DURING "THE MONTHS DECEMBER TO FEBRUARY."

THE AFFINITIES OF DIFFERENT POPULATIONS ARE EXPRESSED BY THE ARROW-MARKS, INDICATING THEIR PROBABLE ORIGIN

Text Figure 22—*contd.*]

(CONTINUED)

YEAR	SEASON	MEKRAN AREA	LASBELA AREA	SIND-RAJPUTANA AREA
1936	WINTER	(XII-II) 52 : 36 12 / 63 37 (INCLUDES INCURSION FORMS)	(XII-II) 52 40 8 / 57 43	OVER WINTERING IN THAR (I-II) 36 11 3 / 41 59
	SPRING	MODERATE BREEDING. SPRING BROOD ON REKS (IV-V) 64 31 5 / 56 44		(FEW LOCUSTS)
	SUMMER	(INCURSION AFTER 27 V) 20 76 4 / 83 15	(V) 17 75 8 / 73 27	CHACHRO (VI) 35 : 6 4 / 77 : 23 (EARLY MIGRANTS)
		(VI-VIII) 52 44 4 / 62 38	(VI-VII) 53 37 4 / 62 38 (LIGHT BREEDING)	DESERT AREA (VII) 70 : 25 : 7 / 75 : 21
	AUTUMN			EXTENSIVE BREEDING (VII-V) THAR: MALANI, NEW GENERATION
			(IX) 65 31 4 / 50 50	(VIII) 88 11 1 / 96 10 FIRST BROOD NORTHERN AREAS
		(X-XI) 60 39 1 / 63 37	(X-XI) 67 30 3 / 45 55	LATE BROOD (X-XI) 72 27 1 / 48 52
1937	WINTER	(XII-II) 37 38 5 / 52 48	(XII-II) 64 35 1 / 44 56	MOKH (XII-II) 73 : 25 2 / 42 58 (OVER WINTERING)
	SPRING	NO BREEDING ON COAST. (LIGHT BREEDING IN INTERIOR) (IV-V) INTERIOR BROOD 78 19 3 / 68 32		(III-IV) LIGHT BREEDING IN NORTHERN DESERT.
	SUMMER	(VI) MIGRANTS AT PASNI 71 23 0 / 51 43	SHEH LAKHRA OUT-BREAK CENTRE (V-VI) 74 25 1 / 55 41	
		(VI-VIII) 67 32 1 / 57 43	(VI-VIII) 69 27 4 / 57 43	(VI) 55 : 43 2 / 71 23 (SUMMER MIGRANTS)
	AUTUMN			HEAVY BREEDING. I st BROOD (VI-VIII) AND BROOD (IX-VI)
			(IX-X) LIGHT BREEDING	(VIII) I BROOD 55 42 3 / 81 19
		(IX-XI) 34 41 5 / 76 24	(IX-XI) 53 45 2 / 72 28	(IX-XI) II BROOD 58 33 8 / 77 23
1938	WINTER	(XII-II) 58 38 4 / 63 37	(XII-II) 33 42 5 / 75 25	CHACHRO AREA (XII-III) 71 : 27 2 / 83 : 17 (OVER-WINTERING)
	SPRING	LIGHT BREEDING (III-V) INTERIOR NEW GENER 64 36 0 / 54 46	KACHHI-BOLAN (V) NEW GENERATION 26 41 3 / 74 26	
	SUMMER	(VI-VIII) 66 31 3 / 48 52 (INCLUDES SUMMER MIGRANTS)	(VI-VIII) LIGHT POPULATION 72 41 7 / 50 50	(VI-VII) THE WHOLE AREA 45 : 5 : 0 / 60 : 40
				LIGHT SUMMER BREEDING (VII-X)
	AUTUMN			NEW GENERATION SOUTHERN DESERT 48 : 52 : 0 / 61 : 39 (IX-X)
		(IX-XI) 71 : 29 : 0 / 56 : 44	(IX-XI) 53 44 3 / 75 : 21	
1939	WINTER	?	(XII-II) 69 31 0 / 66 34	

EXPLANATION:—THE BIOMETRICAL FACIES OF THE LOCUST POPULATION OBSERVED IN THE AREAS CONCERNED HAVE BEEN BRIEFLY EXPRESSED BY THE NOTATION USED ABOVE, WHICH GIVES THE PROPORTIONS OF THE PHASES - SOLITARIA, TRANSIENS AND GREGARIA - IN PERCENTAGES OF THE TOTAL POPULATION EXAMINED IN THE NUMERATOR, AND THE PERCENTAGES OF FORMS WITH SIX EYE-STRIPES AND SEVEN EYE-STRIPES IN THE DENOMINATOR, AND THE MONTHS OF THE YEAR IN BRACKETS SHOWING THE PERIOD OF COLLECTION THUS,

(XII-II) 69 : 31 : 0 / 66 34 INDICATES THE FACIES 69 S 31 T : 0 G 66 (6) : 34 (7)

COLLECTED DURING THE MONTHS DECEMBER TO FEBRUARY

THE AFFINITIES OF DIFFERENT POPULATIONS ARE EXPRESSED BY THE ARROW-MARKS, INDICATING THEIR PROBABLE ORIGIN

During the third and fourth weeks, there were reports from the niabats of Pasni (Kulanch ilaqa) and Tump (Asi-abad) in Mekran about the appearance of locust swarms attacking the standing crops, cotton, *mash* (pulses) and *sohru* (red sorghum). In Kulanch, it was, moreover, reported that "hoppers had also hatched in large numbers."

Swarms had also appeared in the Mirpur-Nasirabad niabat of Kachhi during the week ending the 25th June, attacking the standing crops and the infestation would appear to have persisted till the 1st week of July. In his report for the fortnight ending 10th July 1926, the Political Agent, Sibi stated that cotton crops in the village of Kurk of Sibi tahsil had been damaged by locusts. From the diary of the Naib Wazir, Mekran, it is seen that locusts had been damaging jowar crops in Kolwa towards the close of July.

From these data, it is evident that from the middle of June, locust swarms had begun to appear in Kulanch, Tump and Kolwa in Mekran and in Mirpur-Nasirabad in Kachhi and at Kurk in Sibi tahsil. It is possible that these were migrants coming from the west derived possibly from outbreak centres in Iran or eastern Arabia.

The mention of hoppers hatching out in Kulanch during the latter half of June would indicate that this area had served as one of the outbreak centres producing incipient swarms in 1926. It may be considered probable that adults emerging in April from the hoppers bred on the coastal reks in February-March had migrated into the interior areas such as Kulanch and the Kech valley and possibly similar locations in Persia, and had laid eggs in the sandy beds of water-courses, leading thereby to the formation of incipient swarms.

In this connection it may be mentioned that there was fairly heavy and widespread winter rain in October in *Persia* and *Oman*. There was, similarly heavy rainfall (about 250 m.m.) at about the same time in October-November 1925 on the *Red Sea Coast* near Port Sudan [Maxwell Darling, 1936] and in this area Johnston [1926] first observed the formation of incipient swarms. Since the Oman area is situated in a latitude (24-25 N. Lat.) where the temperature conditions are not unfavourable for winter breeding, it is possible that breeding had occurred here and possible also in the interior of southern and central Arabia. The swarms that appeared in June 1926 in Mekran and Kachhi were probably derived from centres of incipient swarming that had developed in East Arabian areas (and, in view of the further knowledge of the migratory capabilities of locusts obtained during recent years, possibly even from outbreak centres further west on the Red Sea Coast of Arabia, Sudan and Eritrea).

II. *Summer 1926*: (July-August 1926)

As already mentioned, swarms had reached the Kachhi and the Sibi areas early in July. Enquiries made in Jodhpur State by the writer in 1932 showed that swarms had reached the *Mallani* Pargana early in July-August (month of *Savon*) from the west and had led to extensive breeding in many of the desert Parganas of Jodhpur (Sheo, Mallani, Sanchor, Sankra, Parbatsar, Siwani etc.) [Rao 1933]. In the Thar-Parkar district of Sind, the earliest record of infestation is in regard to the emergence of hoppers towards the close of August at Gadra and sundry other villages in Chachro Taluk,—an area adjoining the Sheo Pargana of Jodhpur State. This would indicate that swarms had probably appeared in July and had laid eggs during the 1st fortnight of August. From the report of the Deputy Collector, Thar area it would appear that almost all the desert

taluks of Thar-Parkar district had been similarly infested during August-September necessitating the destruction of hopper bands by trenching. It was reported that towards the end of August and during September locust flights had passed from the north-east or east, from Marwar side, into the various desert taluks: Chachro, Nagar Parkar, Mithi and Diplo and had laid eggs extensively. This may be correlated with the passage of several depressions from the Bay of Bengal that traversed the Rajputana and Gujarat areas and passed into Sind during the second and fourth weeks of August and during the first fortnight of September.

In the Lasbela area, the first record of a swarm is at Sheh Lakhra on the 24th August attacking kharif crops. Since swarms are known to have passed through Mekran (Kulanch and Kolwa) during July-August, it is possible that flights had occurred prior to the 24th August in this area but had not been reported. Similar should have been the case in the Karachi area also, where the first record of swarms was at Jati, Shah Bundar and Sujawal on the 25th September reported to be destroying *bajri, til* and *jowari*.

III. *Autumn 1926*: (*September-November* 1926)

In the course of the progress of a depression moving westwards from the Bay of Bengal into Gujarat and passing into the Arabian sea between Gujarat and Karachi, very heavy rainfall was recorded in south Rajputana, south Sind and the Lasbela areas. Karachi had about 14″ on the 5th and 6th September, Sonmiani (Lasbela) about 5½″, Mithi, 10″ and Barmer 8″. The depression being accompanied by strong easterly winds, it would appear that swarms of yellow locusts were swept westwards from Rajputana into the southern Sind and Lasbela areas; and extensive oviposition apparently occurred, during September and October in all suitable sandy soils in these regions. Consequently widespread emergence of hoppers was reported in many parts of Lasbela, and on the Hab area of Karachi and all over the desert areas of Thar-Parkar district and Mallani. It is also likely that a fair proportion of the locusts concerned in such late breeding (September-October) was represented by individuals of the new generation that had become adult by the end of August or early in September. Whereas the great majority had become adults by the close of October, some hoppers were still noticeable in parts of these areas even up to the middle of November.

Distribution of Breeding in the Desert in 1926

Observations made during the swarmless period 1932-1939 in Rajputana, Baluchistan and Sind have shown that locusts of the solitary type are generally able to reach localities in the desert where a fair amount of rain has fallen and that breeding usually results in case soaking rainfall of two inches or over has been received. On the other hand, breeding is not noticeable in areas where rainfall has been scanty or absent.

Charting the monthly rainfall figures for June, July, August and September, 1935 for the following stations in the Sind-Rajputana desert as representative of typical tracts: (*vide* Pl. 43 Fig. 3) *Chachro* for Thar Desert; *Barmer* for south-western Marwar: *Jodhpur* for central Marwar, *Phalodi* for north-western Marwar and east Jaisalmer, *Jaisalmer* for western and southern Jaisalmer, *Bikaner* for west Bikaner and *Rajgarh* for east Bikaner, it is seen that there was little rainfall in June, and general and fairly good rainfall in July almost all over the desert, *little rainfall* in August except in Bikaner, and light rain in September in

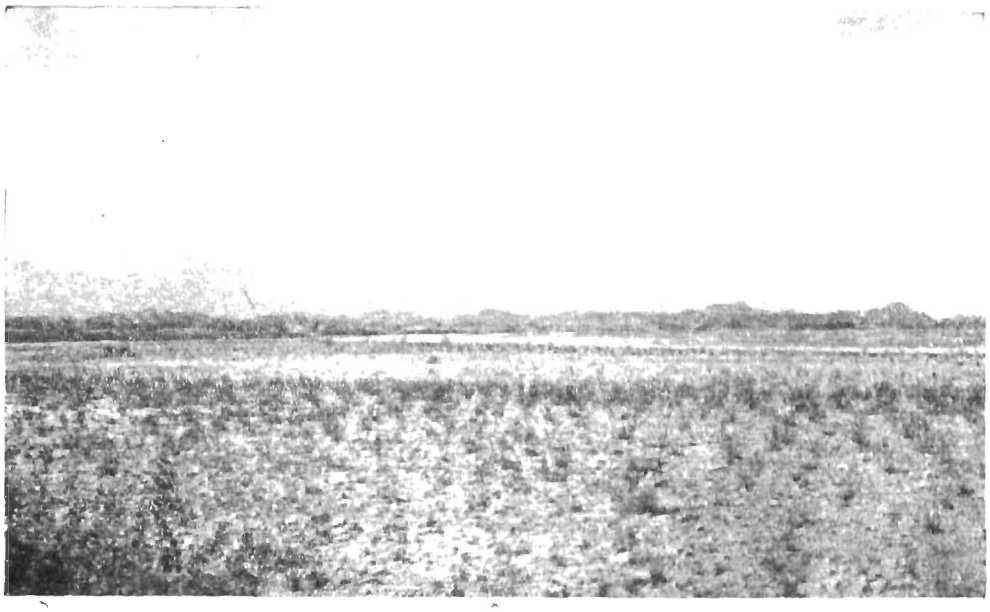


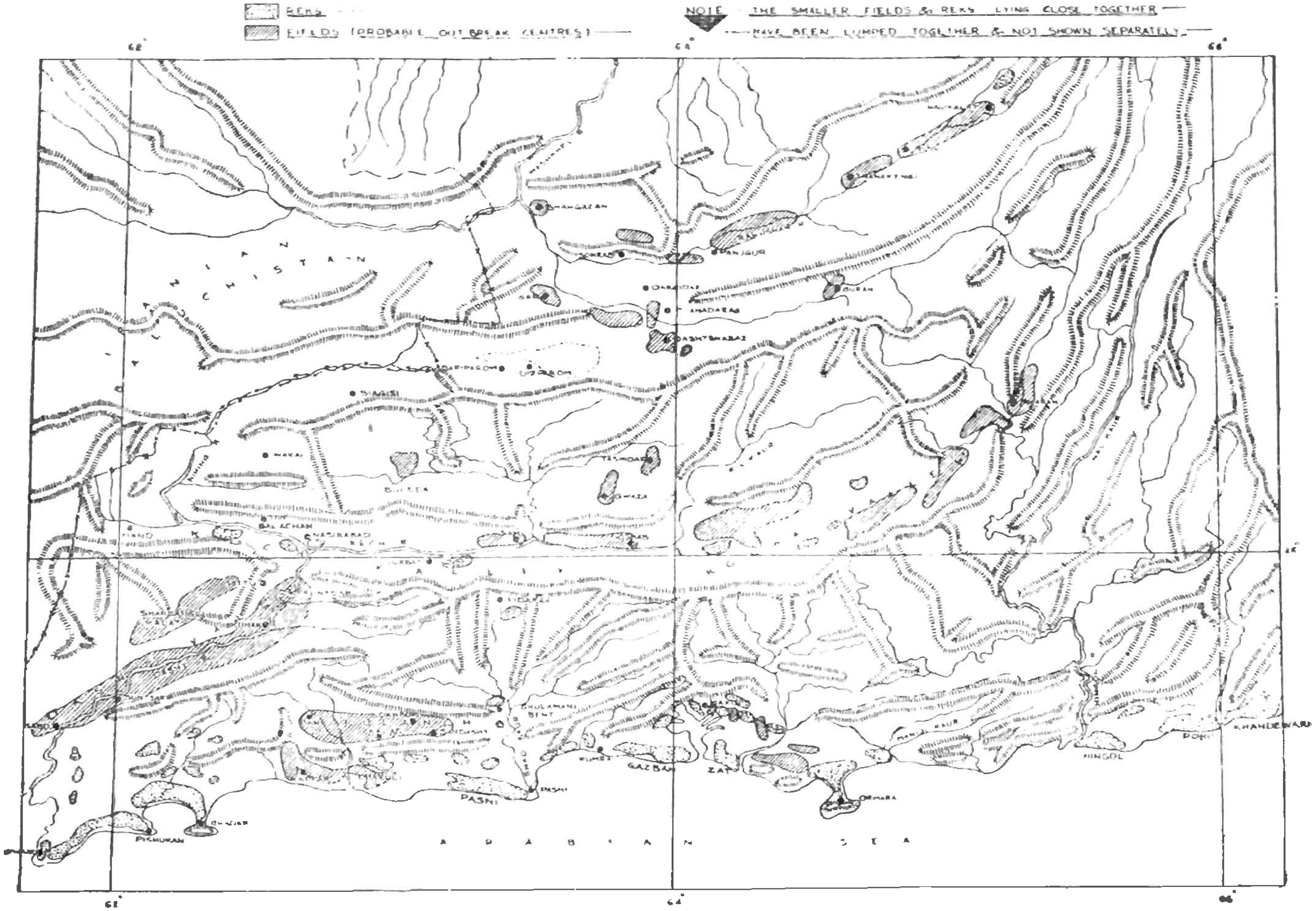
Plate 39.—*Fine silt soils on the banks of the river in the Dasht Valley*: Usually cultivated after the receipt of floods; ideal ground for egg-laying by locusts. Outbreak-centres were recorded in these areas in 1911 and 1923.

Plate 40.—*Outbreak centre at Goth Safar Khan near Sheh Lekha in Lasbela* in February-June, 1937: Field found overgrown with camelthorn and grasses when examined in November, 1937. Large numbers of hoppers and adults were found in this field, in which *jowari* had been grown during the spring months.

Text Figure 23]

MEKRAN AREA

SHOWING THE REKS AND THE PROBABLE OUT-BREAK CENTRES



Bikaner and south Marwar. General breeding of the solitary locust was noticed to have started after the July rainfall especially in Thar, Marwar, and Jaisalmer, but very little further breeding took place on account of the deficiency of rainfall in August and September.

A similar chart of the Sind-Rajputana desert areas for 1926 (*vide* Pl. 43, Fig. 1) shows: that there was no rainfall in June. There was fairly general, though comparatively light rainfall in July, except in Bikaner where it was fairly heavy. In August there was fairly heavy rainfall almost all over the desert; and in September, there was little rainfall in the northern parts of the desert area, but heavy precipitation in the southern parts: Thar and south Marwar. It would appear that in July there was probably fairly general breeding all over the desert—presumably of the solitary type as in July 1935; in August, gregarious breeding started in many parts of the desert; Thar, Sheo and Mallani (south Marwar), and, possibly, south Jaisalmer. In September, locusts would seem to have been swept into Thar and south Marwar in the course of the passage of depressions from the middle of August to the middle of September, leading to intensive oviposition and breeding during September-October in Thar and the southern Parganas of Marwar, which would appear to have been the main source of the swarms that later on invaded Gujarat, Sind and the Punjab.

Available records of breeding in the autumn of 1926. Although it is fairly certain that breeding had occurred over the greater part of the Sind-Rajputana desert, actual records of the existence of hoppers are available only in regard to the desert areas of the Thar-Parkar district. In a report on the locust infestation in Thar-Parkar district during 1926-27, Mr. J. Ansari, Divisional Superintendent, East Sind, said: "It would appear that locusts first entered the Chachro Taluk from Jodhpur territory at the beginning of August 1926 and laid eggs, from which hoppers developed. By the end of the month, infestation would appear to have spread into Nagar Parkar, Umarkot and Diplo talukas. Early in October 1926, the hoppers developed from the eggs became innumerable and began to attack crops, causing damage to the extent of 8 annas in the rupee. Later on, late sown bajri was totally damaged as also the guar crop. The invasion was so acute that for ten days people in big villages like Mithi and Islamkote could cook their meals only with great difficulty. The fully fledged adults flew all over the area and attacked the leaves of all plants except 'Ak' (*Calotropis*) and 'Neem' (*Melia*)."

Mann and Burns [1927] stated that hoppers had been observed in several places in the Karachi taluka, and that they were in abundance in the *dehs* near the Hab River. From the Lasbela records, it is seen that eggs were laid in September after heavy rainfall in the Uthal, Pabuni, Sonmiani and Habnadi areas, hoppers being found in good numbers in October.

It is thus seen that locust multiplication had occurred over a fairly extensive area, from Lasbela in the west up to south Marwar in the east, and also that the breeding period had extended up to the middle of November.

Autumn Flights 1926

The earliest batch of hoppers would appear to have become full-fledged by the middle of September and the new generation of locusts to have begun flying during September and October. Pink swarms began to appear in the various districts of Sind from the direction of the desert areas and gradually to proceed westwards into the Baluchistan areas.

Other swarms probably produced in the southern areas such as Nagar-Parkar, Mallani and Sanchor had presumably flown south into the Cutch area and thence reached Radhanpur and Wankaner during November. Further flights would appear to have occurred carrying the swarms further south into the States of Kathiawar and eastwards into Palanpur, Mahikanatha, Ahmadabad and Broach during December, where wheat, cotton and pulses were damaged. The swarms would appear to have spread throughout Kathiawar during January 1927 and also to have moved south and east into the Surat area and reached Taloda taluka in West Khandesh. No reports of swarms are on record after the 26th February except for a single one from Surat on 20-3-27 [Mann and Burns, 1927]. Apparently the majority of the locusts gradually disappeared westwards flying towards Sind and Baluchistan in the course of February 1927.

In Sind, the pink flights which appeared from October onwards in large numbers caused much damage to the crops all over the province. The direction of flights was generally east to west, but in some cases it was south to north, south-east to north-west or north-east to south-west. In Baluchistan, swarms began to appear from the direction of Sind in Lasbela, Jhalawan and Mekran in the latter half of October and flights continued during the month of November reaching as far as Kech, Dasht and Punjgur, and causing damage to young wheat, barley and cotton. Swarms also reached the eastern parts of Loralai such as Naharkot and the adjoining Kohlu tahsil of Sibi district during November, damaging young germinating rabi crops, coming apparently from the direction of Dera Ghazi Khan district.

Further flights occurred, during December 1926, in the Baluchistan region in Lasbela, Jhalawan and Mekran, and also in Loralai and Sibi areas. Reports indicated that certain flights reached the Chagai district from Koh-i-Pusht in Afghan territory during the last week of December. Presumably swarms that had appeared in Loralai in November-December had evidently passed on across the Quetta Pishin area into Afghan territory and thence southwards into Chagai District.

The earliest reports of the occurrence of locust swarms in the Punjab is on the 16th December in the Rajanpur tahsil coming from the south-west but there is little doubt that they had reached Dera Ghazi Khan district much earlier, *i.e.*, during November, since flights had been reported in November from Barkhan tahsil in Loralai district coming from the direction of Dera Ghazi Khan.

During December, flights occurred in the Dera Ghazi Khan, Multan, Muzaffargarh, Montgomery, Jhang and Mianwali districts, the main direction of flights being south-west to north-east. Certain swarms are reported to have passed through the Bahawalpore State during December.

Summary of Events in 1926: (*vide* Pl. 42 Fig. 1)

Following heavy rainfall in January in Baluchistan (in Mekran especially) heavy breeding of the solitary type locusts had presumably occurred in the coastal areas leading to an increase in the locust population by March-April. In consequence of early and fairly heavy precipitation in October in the Oman area, a similar increase of population had probably occurred in that area also. The gregarious breeding that occurred in Kulanch in May 1926 might have been due to the activities of immigrants from the coastal areas or from areas outside Indian limits, causing the formation of an outbreak centre there.

In June, swarms from Kulanch and similar outbreak centres outside India appeared in various parts of Mekran and were observed in Kachhi and Sibi by the end of the month. In July, flights apparently reached the Sind-Rajputana desert areas, and scattered breeding (presumably) of the solitary type probably occurred in many parts of the desert in the wake of good rainfall.

In August further flights appeared in Mekran, especially in Kolwah, and reached the Lasbela and Karachi areas. In the desert, movements of locusts from the north and north-east towards the south-west occurred in the course of the passage of certain Bay Depressions and led to concentrated breeding in south Marwar and in the Thar area of Sind in August and September. In consequence of unusually heavy rainfall in September in the Karachi and Lasbela areas, heavy breeding occurred here also during September-October. As a result of heavy multiplication in Lasbela, Karachi, Thar and south Marwar areas, large swarms began to fly during October-November, (1) partly south into Cutch, Western Indian States, Kathiawar and north Gujarat, (2) partly westwards into Sind and south Baluchistan, ultimately passing beyond the frontier, and (3) partly into the Punjab and north Baluchistan. Thus was a new cycle of locust infestation brought into being in 1926 in India, that continued with almost unabated severity till 1931.

YEAR 1927

A. Weather Notes

I. *Winter-Spring Rainfall* 1926-1927: (Monthly total in inches)

1926-27	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Iran							
Bushire	6·41	2·16	0·12	1·25	0·06	..	8
Jask	..	1·84	..	2·01	..	0·24	5
Seistan	..	0·47	0·14	0·69	0·05	0·03	..
Meshed	0·59	0·71	0·35	1·92	1·35	1·56	1·18
Ispahan	1·15	0·48	0·21	0·50	0·56	1·56	0·05
E. Arabia							
Muscat	..	1·26	..	0·68	..	0·39	..
Baluchistan							
Pasni	..	0·76	0·42	2·94	..	..	..
Panjgur	..	1·15	0·19	1·57	0·10	0·21	..
Turbat	..	1·17	0·11	3·54	..	..	..
Bela	..	..	0·51	0·63	..	0·09	0·31
Quetta	0·05	1·32	0·71	2·02	0·57	0·12	..
Chaman	0·03	2·79	0·57	2·27	0·74	0·47	..
Nushki	..	1·14	0·82	1·44	0·52	0·19	..
Kalat	..	1·01	0·78	1·75	0·38	0·25	0·01
Sind							
Karachi	..	..	0·10	1·12	..	..	0·05
Jacobabad	..	..	0·04	0·17	..	0·02	0·03
N.W.F. Province							
Peshawar	..	0·07	0·03	0·72	1·06	1·41	2·05
Bannu	..	0·06	0·04	0·29	0·36	0·91	0·13

1926-27	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Punjab							
Rawalpindi	..	0·83	2·05	2·18	1·29	1·00	0·79
Gujrat	..	0·14	0·23	0·83	0·74	0·73	3·46
Lahore	..	0·40	..	0·57	0·22	0·31	0·60
Ambala	1·30	0·09	0·03	3·88	1·82	0·53	1·42
Hissar	..	..	..	0·55	1·00	0·09	0·34
D. G. Khan	0·01	0·02	..	0·10	..	0·08	0·20
United Provinces							
Roorki	0·20	..	..	2·11	1·02	0·28	0·65
Agra	..	..	..	1·11	..	0·13	0·33

January was colder than usual in north-west India and rainfall was in defect, but in February, the western disturbances produced abundant rainfall over the whole of north India from Baluchistan to Upper Burma. There was on the whole little rainfall during March, April and May.

II. *Monsoon Rainfall* 1927: (Monthly totals in inches).

1927	May	June	July	August	September
Sind					
Karachi	0·05	2·53	2·40	..	..
Mithi	..	0·55	28·23	1·98	0·39
Chachro	..	0·75	13·44	4·85	0·31
Rajputana					
Barmer	..	0·05	6·43	4·59	0·37
Jodhpur	0·18	0·18	5·72	12·39	1·53
Phalodi	0·12	0·26	3·51	1·89	0·17
Jaisalmer	0·40	0·21	2·13	1·34	0·92
Devikot	..	..	1·85	2·07	0·44
Bap	..	..	3·15	1·33	0·44
Bikaner	0·84	0·11	7·11	6·23	1·42
Ajmer	0·59	0·75	5·68	16·04	2.8
Punjab					
Rawalpindi	0·78	0·35	5·52	6·38	2·02
Gujrat	3·46	1·01	4·87	4·45	0·77
Lahore	0·60	0·54	5·52	3·94	0·44
Ambala	1·43	0·94	11·37	9·65	1·94
Hissar	0·34	0·04	9·68	1·89	0·52
D. G. Khan	0·29	0·72	0·68	0·64	..
United Provinces					
Roorki	0·65	0·59	7·54	13·03	1·98
Agra	0·33	0·83	6·71	13·04	3·42
Baluchistan					
Pela	0·30	..	2·76	0·35	..
Sonmiani	..	..	4·60	1·65	..
Rindli	..	..	4·35	1·80	..
Loralai	0·73	0·09	2·16	0·47	..

The monsoon extended into north-east India by the 1st week of June, and under the influence of a storm formed off the Orissa Coast on the 16th June moved up to western United Provinces through the Central Provinces on the 20th. It was weak thereafter till the 4th July, when the Bay current advanced along the Gangetic Plain into east Punjab, and then extended into Rajputana and Sind by the end of the 1st week. Two depressions were active between the 10th and the 19th and produced some rainfall in United Provinces, Punjab and Rajputana. A deep depression from the head of the Bay moved towards south Rajputana, through the central parts of India, between the 23rd and 27th July and caused excessive rainfall in Baluchistan, Sind, Gujarat and west Rajputana. In August three depressions formed at the head of the Bay and travelled westwards into the United Provinces and beyond. All of them brought about rainfall in the Rajputana area and especially the second one (active between the 16th and the 22nd), which travelled up to upper Sind, caused very heavy rainfall in Marwar (though very little in Bikaner). The monsoon showed signs of retreat in N. W. India after the 4th September.

B. Locust Data: 1927: (*vide* Pl. 45)

I. *Winter* 1926-27: (Dec. 1926—Feb. 1927)

Owing to heavy rainfall in September, breeding continued till late in the autumn of 1926 in the desert areas of Sind and Rajputana and the swarms that were produced at the fag-end of the season in October-November became affected by the onset of cold weather and moved rather tardily, so that the major part of them remained within Indian limits during winter.

During January, numerous swarms were found in the central and south-western districts of the Punjab, the northern-most limit of distribution being Jhelum. Swarms were active throughout the winter in Sind except in Upper Sind Frontier, and in Baluchistan, they were reported from Mekran, Jhalawan, Chagai, Lasbela, Sibi and Loralai. Damage to crops due to the activity of swarms was also reported in the Western India States, Kathiawar and Gujarat (Broach, Ahmadabad, Kaira and Surat) during January and February.

During February, good rainfall was received all over northern India and associated therewith, there was a general seasonal rise of temperature. As a result, swarms became active in the Punjab and spread northwards into Attock and Rawalpindi, into parts of N. W. Frontier Province and into Jammu in Kashmir territory; and eastwards into Ambala and Karnal, and thence into the western districts of the United Provinces such as Saharanpur, Muzaffarnagar, Dehra Dun and Meerut.

In Baluchistan, swarms moved into Nasirabad and Kachhi from Sind and thence along the Bolan and Nari valleys into hill areas such as Kirta, Bolan, Harnai and Loralai. Further south, locusts gradually flew from Sind westwards into Lasbela and into Jhalawan and Mekran through the Mula Gorge. In southern Baluchistan, swarms from coastal Mekran moved into the upland valleys of the hinterland and flights from Iranian Baluchistan reached Kharan and Chagai.

Egg-laying commenced during the month in Chagai, Jhalawan and Kachhi in Baluchistan and in Ambala district in the Punjab.

II. *Spring* 1927: (March-May 1927)

Baluchistan. With the rise in temperature, swarms became more active and during March and April, they gradually advanced from the low-lying plains along the hill valleys into the uplands of Baluchistan. In the Bolan area after laying eggs at Kirta, locusts flew up the valley and reached the Mastung and Quetta areas. In the Nari River area, locusts reached Sangan and laid eggs there, and from thence followed the river valleys towards Shahrigh, Kach and Pishin on one side and into the Loralai district on the other. Swarms reached the Zhob district in March from Musakhel side (Loralai district).

Flights from the Iranian areas reached Kharan and Chagai and thence spread into the Shorawak and Kandahar areas in April. From Shorawak, locusts entered the Chaman, Spinotiza and Shelabagh areas and later, the Toba uplands (over 7,000 ft. high).

In Mekran, extensive egg-laying occurred in March in Dasht, Nigor, Kulanch, Turbat, Tump, Buleda and Panjgur areas; in Jhalawan, in the Mashkai, Khuzdar, Zedi and Wadh areas; in Sarawan, around Kalat, Mastung, Sheikhwasil and Sariab; and in Chagai, in the Nushki, Dalbandin, Chagai and Shorarud areas. In addition, it was evident that oviposition had occurred also in Kharan and in the Shorawak and Registan areas of Afghanistan.

In Upper Baluchistan, breeding occurred in parts of the Quetta tahsil; in Chaman area in Shelabagh and Toba Achakzai in the Gulistan, Karezat Kakari, Pishin and Toba Barshore circles of Pishin tahsil; in the Hindubagh tahsil of Zhob district; at Chotair in Loralai district: and in the Sangan, Shahrigh and Kach areas of Sibi district. In Kachhi extensive breeding occurred in the Bhag, Dadhar, Lahri, Gandhava and Mirpur-Nasirabad niabats in February-April, and in the Bolan areas, at about the same period, at Kirta, Rindli and Mashkhaf. There was thus very extensive breeding in the spring months in the greater part of Baluchistan.

Punjab. Swarms were active in many parts of the Punjab during March and April, but they were concentrated specially in the northern districts and in the submontane areas, as these had received more rainfall than the rest of the province. Eggs were laid in 12 districts:—in Ambala and Ludhiana; in Jhelum, Rawalpindi, Mianwali, Attock and Gujarat; in Lahore, Multan and Montgomery; and in Ferozepur and Gurgaon. Hoppers were found in all these areas in April and May; and as far as possible destruction measures were taken by the administration.

East Punjab States and United Provinces. Records show that swarms reached Dehra-Dun and Sirmur State (East Punjab States) from the west in March, that eggs had been laid on both sides of the Jumna in the Sirmur State and western Dehra-Dun and that the hoppers that emerged caused damage to Tea Gardens to the extent of over 1 lakh rupees, [Richards, 1931]. There is a report from Bengal to the effect that a swarm of locusts had passed through the Rajshahi district in March 1927, which would indicate that, although not reported, overwintered locusts from Punjab or Rajputana had passed through the United Provinces and Bihar early in the year.

N. W. F. Province. Invasion of yellow locust swarms from the northern districts of the Punjab was reported to the Imperial Entomologist, Pusa, from Peshawar about the middle of April. Between the 19th and the 22nd April, extensive oviposition was observed on the Tarnab Farm at Taru Jubba and the area round-about, and hatching was observed from

the 7th May onwards. The hoppers were found attacking clover, peaches, potatoes, sugarbeet, watermelons, apricot etc. It is likely that many other parts of Peshawar had been similarly infested. Oviposition is also reported to have taken place in the Hazara district of N. W. Frontier Province in April [Husain 1941].

Extra-Indian Areas. Very little information is available. According to Predtechensky [1935], over-wintered swarms from the lowlands of Persian Mekran advanced northwards in March-April along Duzdap and Kash into Khorasan, where egg-laying occurred in April-May. There was similar breeding in the Kerman area in April. According to Uvarov [Uvarov 1932], "in February 1927 the neighbourhood of Bushire, on the Persian Gulf, was invaded by swarms apparently coming from Arabia. The new generation bred in this area reached the adult stage in May and migrated northward."

May 1927. Hoppers bred in Mekran, Chagai, Kachhi and other comparatively low-lying areas assumed wings by the end of April or the early part of May, and began to form large pink flights directed towards the east or north-east.

In Baluchistan, large pink flights were found entering Sarawan early in May from Nushki side, and Jhalawan, at about the same time, from Kharan and Nushki, in Gidar and Surab areas. At about this period an influx of swarms from the west was noticeable in the Kachhi area and in the Nasirabad division of Sibi district.

In Sind, where few swarms were noticed in March and none at all in April, an influx of pink swarms from the west was recorded from the week ending 14th May. In Lasbela also the earliest swarms appeared on or about the 10th May from the north or north-west.

In Punjab, the first adults of the new generation began to appear by the middle of May and the young adults formed swarms, which gradually passed south or south-east towards the United Provinces, East Rajputana and Central India by the end of the month. Some of these flights appeared in Karnal and Hissar and passed on into the United Provinces by the end of May.

III. *Summer* 1927: (June to August 1927)

June 1927. Flights from the west, composed partly of locusts bred in Baluchistan and partly of those from regions beyond Indian limits such as Iran and Afghanistan, which commenced by the middle of May, continued throughout June in Sind and the Punjab. The general movement of these swarms is usually from west to east or south-west to north-east, and flights reaching Sind usually pass into Rajputana and thence into Central India and Central Provinces. Those reaching the Punjab amalgamate with the swarms bred in that province and pass thence into the United Provinces or Central India, from which they move further east.

In 1927, information in regard to locust movements in Rajputana and Central India is very scanty. It is, however, known from the data recorded in the season and crop reports of the Central Provinces Gazette that swarms passed through Jubbulpore district on the 25th May and through Damoh district on the 26th. In the second week of June locusts visited Saoner tahsil of Nagpur district and in the third week, certain swarms visited Sarangarh, Kawardha and Surguja States. In the case of Surguja, the flight was on the 20th June and the direction was from east to west,

which coincided with the wind direction prevalent in that area in consequence of the passage of a storm over the east Central Provinces. The occurrence of pink swarms in the Parlakimedi area of Ganjam district (Orissa) on the 16th June would indicate that some of the flights known to have occurred about this time in east Central Provinces had reached as far east as the Orissa coast.

A small flight of locusts passed just north of the Pusa Estate (Muzaffarpur district) in Bihar on the 28th June [Fletcher, 1928], and another was sighted at Muzaffarpur between the 28th and the 30th June [Husain 1951]. A flight visited Palamau on the 5th July and another swarm was reported from Bhagalpur during the first fortnight of the month [Husain, 1941], and a second flight was recorded at Pusa on the 11th July 1927 [Isaac, 1929].

Some at least of these flights should without doubt have passed through the United Provinces, but the available records for this area are very scanty. According to Richards, 'flying swarms were present in the hill districts (Almora, Garhwal, Nainital and Dehra Dun) till August. Many swarms also crossed the United Provinces from the west (presumably in June-July) and were lost track of, newspaper reports indicating that they crossed into Bengal and Assam and disappeared eastwards.' [Richards, 1931]. There is positive confirmation of swarms reaching Bihar, but none in regard to their visiting Bengal and Assam, which is not very likely to have happened till September, since the winds during the prevalence of the Bay monsoon are adverse to such movements.

Summer breeding: 1927

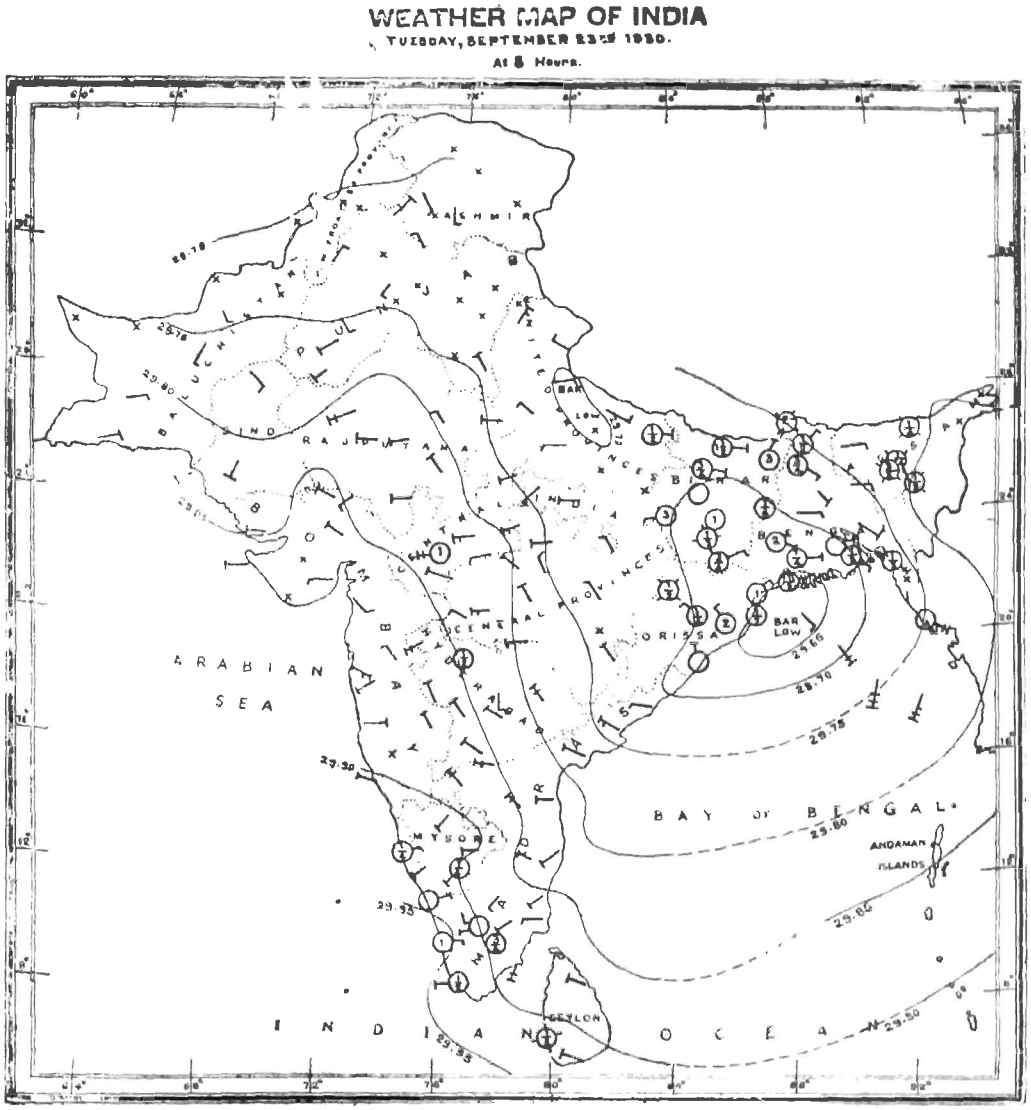
Baluchistan. Whereas in the areas of Mekran, Kharan, Chagai and Kachhi hoppers reached the adult stage by the middle of May, breeding continued in the upland areas of Quetta-Pishin, Sibi (Kach), Zhob (Hindubagh) and Sarawan (Kalat) till the middle of June and in the higher ranges such as Toba Barshore even up to July.

During July, there was a fair amount of rainfall in the eastern parts of Baluchistan, as in Kachhi and Lasbela. Light summer breeding occurred in the lower altitudes of Sibi district, as at Sangan and Khajak. There is no record of breeding in Lasbela, but as some breeding is known to have taken place in the neighbouring areas of Karachi district, it is possible that some light breeding had occurred in the Sonmiani-Hab areas.

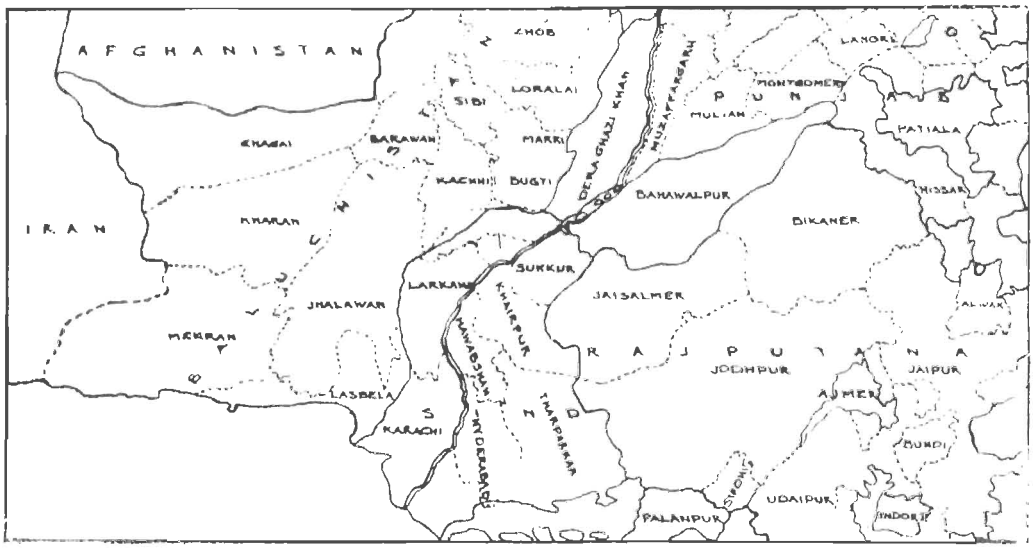
The Punjab. Although swarms were found active in most parts of the Punjab during June, July and August, oviposition occurred only in the eastern and south-eastern parts: *viz.* Hissar, Gurgaon, Rohtak, Ferozepur, Ludhiana, Jullundur and Montgomery. This may be correlated with the fact that monsoon rainfall was very much in defect in the Punjab in 1927, except in the eastern districts. No breeding was noticed in any of the districts of the United Provinces.

Sind-Rajputana Areas. During July, there was heavy rainfall in the southern part of Sind from Hyderabad eastwards and moderate rainfall in most parts of Rajputana except Jaisalmer. Fairly heavy breeding took place in several parts of the Thar-Parkar desert (Chachro, Umerkot, Khipro, Sanghar, Nagar-Parkar etc.) and in Karachi district (Gadap, Tatta, Kohistan etc.) during July-August. Mithi and Diplo talukas recorded very heavy rainfall, on which account, probably, there was no breeding in these areas.

Text Figure 24]



Text Figure 25]



Skeleton map indica ing the names of the divisions of the Sind-Rajputana area included in Plates No. 43 and No. 44.

As regards Rajputana, official records are very few in regard to locust occurrence. The only available information is about the occurrence of "Phaka" (hopper bands) in Phalodi, Nagour, Barmer, Balotra and Jodhpur parganas in August. Enquiries made also showed that breeding had occurred in Sardarshahr and other southern Parganas of Bikaner. A study of the monthly rainfall data during the monsoon months in various states of Western Rajputana would indicate that, on account of paucity of rainfall, there was no possibility of egg-laying either in Jaisalmer or the northern parts of the Bikaner State (*vide* Pl. 43, Fig. 2). On the other hand, the precipitation would appear to have been too heavy, especially in August in the central and south-eastern Parganas of Marwar to be favourable for breeding. It is probable that some breeding had occurred in Alwar and Jaipur, though no data are on record.

On the whole, locust breeding took place in many parts of Marwar and Bikaner in the monsoon period, but was not excessive. Rainfall in August was too scanty in many parts of the desert and rather too excessive in the southern and south-eastern area to be favourable for breeding. As there was little rainfall, on the whole, in N.W. India in September, late breeding did not occur.

IV. *Autumn* 1927: (September-November 1927)

Breeding: *Sind*: Breeding continued in the Chachro, Sanghar and Khipro talukas of Thar-Parkar district during September and hoppers were found in these areas till the middle of October. Hoppers were also observable in Karachi taluk throughout September.

The Punjab. Breeding continued in September, especially in the various tahsils of Hissar district, where special attention was paid to their destruction.

Autumn Flights. During September, adults of the new generation began to fly about soon after getting wings. Swarms of pink locusts appeared in various parts of Sind from the direction of Rajputana and caused much damage to crops. The general trend of the direction of their flights was towards the west, east to west, north-east to south-west or south-east to north-west. Flights intensified in October and November and passed through all the districts of Sind in the direction of Lasbela, Jhalawan, Mekran and Kachhi in Baluchistan. Swarms visited Kolwah, Tump, Kulanch, Dasht and Panjgur in Mekran during October and November. In Lasbela, locusts were reported to have done extensive damage to the standing crops. Swarms also visited the eastern parts of Loralai, Barkhan, and Musakhel, presumably from the direction of the Punjab. During December, the activity of swarms had become minimised.

In the Punjab also autumn flights were in evidence in Hissar, Gurgaon, Montgomery, Lyallpur, Multan and Shahpur districts, the general direction being from south to north and east to west. No flights were reported during December. On the other hand, in the United Provinces there were no reports of locust flights during September, October and November, but during December some swarms were reported to have been active in the hill areas of Dehra Dun and in the adjoining State of Nahan.

Flights of locusts appeared in the Western India States Agency during the first week of November, chiefly in Radhanpur, Morvi, Dasada and Santalpur, the main direction being north to south or east to west. Most of the swarms are said to have passed westwards into Cutch. Presumably they had originated in the southern parts of Rajputana.

During the autumn of 1927, there is no indication of any eastward migration, with the exception of the movements into United Provinces.

Summary of Events in 1927: (*Vide* Pl. 45)

(1) Winter rainfall was, on the whole, defective, though rain-fall occurred in December 1926 and February 1927 in Mekran and Upper Baluchistan and in the submontane districts of the Punjab in February-March 1927.

(2) There were numerous over-wintering swarms in the Punjab, in Sind and in parts of Baluchistan, which gradually moved from the plains up the hill valleys into Loralai from Dera Ghazi Khan: up the Bolan and Nari valleys from Kachhi to the uplands of Quetta-Pishin and Sibi (Kach, Harnai, etc.), and up the Mula pass into Jhalawan. Many migrated from the Iranian areas into Mekran, Kharan and Chagai in February-March. In the Punjab, swarms gradually shifted north into Rawalpindi and N.W.F. Province and east into United Provinces (Dehra Dun, Garhwal, Bijnor). Apparently some swarms had travelled even further east, as a flight reaching at the end of March is on record.

(3) Spring breeding occurred all over Baluchistan from March to May (and June in the uplands); in the Punjab in the north and north-eastern submontane districts, as well as in Montgomery, Ferozepur, Gurgaon and Multan. In the United Provinces breeding occurred in Dehra Dun and in the adjoining areas of Sirmur State.

(4) The new generation bred in Baluchistan and in the Punjab began to fly in May and reached Sind, Rajputana and United Provinces. In June swarms were recorded in parts of Central Provinces (Jubbulpore, Damoh, Sarangarh, Kawardha, etc.); some reached the Orissa Coast in Ganjam district by middle of June; others reached various places in Bihar (Palamau, Muzaffarpur and Bhagalpur) in June-July.

There was heavy monsoon rainfall in Sind and Rajputana in July-August and a fair amount of summer breeding occurred, especially in Thar and Karachi and in south Marwar; and in the Punjab, mostly in the eastern and south-eastern districts.

(6) There was fairly heavy west-bound migration in Sind, Baluchistan and Punjab in the autumn months, and a few flights into Western India States and into the hill districts of United Provinces. No eastward migration was noted in autumn.

YEAR 1928

A. Weather Notes 1928

I.—*Winter-Spring Rainfall* 1928: (in inches)

1927-28	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Iran							
Bushire	0·65	4·89	4·52	0·11	0·08	..	..
Jask	0·30	2·80	0·84	..	0·10	..	..
Charbar	0·20	8·49	2·86	..	0·13	..	..
Henjam	0·61	..	..	..	..	..	..
Seistan	..	1·32	0·20	0·12	0·98	..	..
Meshed	0·27	1·28	1·85	1·84	1·39	0·34	60·9

1

3

2

Plate 41.—Desert Locust: Solitary phase adults:
Fig. 1. Adult locust carrying numerous colonies of bright green algae among the cells of the hind-wing; Fig. 2. Micropnotograph of cells of the hind-wing with colonies of green algae; Fig. 3. Adult locust infested by Tyroglyphid mites, colonies of which are to be seen at the base of the hind-wings and at the base of the abdomen. The white dots are the empty moults of mites.

1927-28	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May
E. Arabia							
Muscat	0·40	0·34	1·84	2·21	.	..	..
Bahrein	..	0·45	0·15	..	0·15	..	..
Baluchistan							
Pasni	..	1·57	1·51	0·07	1·00	..	..
Panjgur	..	0·85	0·74	0·88	0·11	..	..
Turbat	0·02	1·33	2·93	0·69	0·28	..	..
Sonmiani	..	0·50	..	0·13	0·10	..	..
Quetta	..	1·11	1·46	2·24	2·86	0·18	0·01
Chaman	..	2·48	1·49	1·28	1·06	..	..
Nushki	..	0·98	0·59	2·62	0·87	..	..
Kalat	..	1·04	0·87	1·18	0·81	0·16	0.03
Rindli	..	0·35	0·24	0·45	..	0·45	..
Sind							
Karachi	..	0·19	0·14	..	..	..	..
Jacobabad	..	..	0·08	0·03	0·04	0·31	..
N. W. F. Province							
Peshawar	1·59	1·59	0·42	2·80	3·92	0·66	0·24
Bannu	..	1·01	0·19	2·31	0·34	0·76	0·06
Punjab							
Rawalpindi	..	0·93	2·26	2·49	1·22	1·96	0·40
Gujrat	..	0·52	0·90	0·51	1·00	0·84	0·02
Lahore	..	1·73	0·25	0·47	0·35	0·73	0·34
Ambala	0·30	1·32	2·76	1·09	0·34	0·55	0·25
Hissar	..	1·95	0.38	0·78	..	0·14	..
D. G. Khan	..	0·32	0·18	0·16	0·15	0·28	..
United Provinces							
Roorki	0·02	0·67	3·42	4·84	0·09	0·84	0·53
Agra	0·80	0·39	0·25	1·33	..	..	0.14

In December 1927, western disturbances were more active than usual and rainfall was largely in excess in N. W. India, but in January 1928, the disturbances were weak and rainfall was in defect. In February, they caused a slight excess of rain. In March and April rainfall was in defect.

II. *Monsoon Rainfall 1928*: (*in inches*)

1928	May	June	July	August	September
Baluchistan					
Sonmiani	..	..	.	..	..
Bela	0·04	..	1·50	2·13	..
Rindli	..	0·20	1·30	0·35	..
Lowalai	..	0·50	1·15	0·20	..
Sind					
Karachi	..	..	0·68	..	..
Jacobabad	..	..	0·40	..	..
Mithi	..	..	2·77	2·51	0·0
Chachro	..		3·03	1·65	0·1

1938	May	June	July	August	September
Rajputana					
Bramer	..	..	2·01	4·19	0·12
Jodhpur	..	..	3·70	6·92	1·20
Phalodi	..	0·22	1·91	2·81	0·32
Jaisalmer	..	..	1·08	2·31	0·13
Devikot	..	..	0·12	3·53	..
Bap	..	0·32	1·00	1·15	0·30
Bikaner	0·14	0·32	3·16	7·52	0·54
Nohar	..	0·70	0·65	4·39	..
Jaipur	0·01	0·64	4·20	2·51	2·00
Ajmer	0·80	0·72	4·90	12·73	2·20
Punjab					
Rawalpindi	0·40	0·40	3·54	1·92	7·40
Gujrat	·02	0·59	6·77	2·75	5·05
Lahore	0·34	1·07	4·14	4·75	4·19
Ambala	0·25	1·54	11·24	3·29	4·21
Hissar	..	2·84	2·78	6·42	0·45
D.G. Khan	..	..	0·61	0·59	..
N.W.F. Province					
Peshawar	0·24	0·02	..	0·26	0·22
Bannu	0·06	0·52	3·19	0·57	..
United Provinces					
Roorki	0·53	1·44	19·38	3·30	6·48
Agra	0·14	0·90	7·11	3·22	2·66

In May 1928, a depression at the head of the Bay on the 12th caused a temporary advance of the monsoon, but did not affect north-west India, where the weather was dry and warm. In June, under the influence of a storm at the head of the Bay, the monsoon extended into north-east India between the 10th and 18th and into east United Provinces on the 19th.

In July three depressions moved westwards from the Bay; the first caused the extension of rainfall into Gujarat, Rajputana and Sind between the 2nd and the 6th and in the United Provinces and east and north Punjab between the 7th and the 10th. The second caused heavy rain from Bengal to Gujarat between the 16th and the 29th and in N. W. India between the 21st and the 23rd, and the third, very heavy rain between Orissa and Central India (25th to 27th) and strengthened the monsoon in Rajputana and United Provinces between 26-vii and 28-vii.

During the first fortnight of August there was a break in the rains in the central parts of the country. The monsoon revived on the 16th and gradually extended into the Punjab only by the 21st so that the drought lasted nearly 3 weeks in N. W. India. During the last week, a depression from the Bay moved through Central Provinces and east Rajputana into Punjab and occasioned heavy rain in these areas, and also further rainfall in Punjab and Kashmir till the 3rd September. The monsoon ultimately withdraw from N. W. India from the 5th September.

B. LOCUST DATA (1928) (*vide* Pl. 46)

I. *Winter* 1927-28: (Dec. 1927-Feb. 1928)

Except for the presence of a few swarms in Sind during December and January and some in Mekran, there was very little of over-wintering. There were no reports of swarms during the winter period in the Punjab, United Provinces or Rajputana.

Early Spring breeding. Fairly good rain was received in Mekran during December 1927 and January 1928, and considerable locust activity was noticed on the coast areas and eggs were reported to have been laid in January in parts of the Dasht valley. During February locusts were found all over Mekran and extensive oviposition and emergence of hoppers were noted in Tump, Mand, Turbat, Nigwar, Dasht and Kulanch areas and, by March, hoppers appeared in the Panjgur area also.

Swarms also appeared in Chagai, Kharan and Jhalawan in February, and oviposition occurred in all these areas in February-March.

II. *Spring* 1928: (March-May 1928)

In March, certain flights from Iran apparently passed north through Chagai into Garmsel in Afghanistan, and others entered eastwards or north-eastwards into Sarawan and Jhalawan. Flights from a western direction were reported at this time from Sibi and Kachhi and from the Bolan area. According to Predtechensky, passage of yellow locusts and egg-laying were noticed in the regions between Kash and Duzdab, and also in the north-western part of Seistan.

During March-April breeding continued in Mekran, Chagai and Jhalawan; egg-laying and breeding were reported in April also from Sibi district (Kach and Manghi), from Jhalawan (Surab, Zehri, Wadh, Bagwana and Mashkai). In Mekran, hoppers reached the adult stage by the middle of April; and began to fly about the country. By the third week of April, pink swarms were found coming in from the direction of Iran. These had probably bred either in Iran or in Oman, as good winter rainfall had occurred in these areas in December-January. These flights passed over various parts of Baluchistan and reached the Punjab (the earliest flight being on 22nd April at D. G. Khan), and Sind (the earliest flight occurring during week ending 28th April). Certain flights which were observed at Attock, and Mianwali on the 24th April had presumably passed *via* D. I. Khan and Bannu districts of the N. W. F. Province. Numerous similar flights occurred during May in the Punjab, where the swarms became distributed all over the province, and in Sind, whence they obviously spread into Rajputana. On the 18th May, a flight was reported by a passing steamer in the Gulf of Cutch. Between the 21st and the 30th May certain swarms were reported from Garhwal, Almora and Dehra Dun in the United Provinces.

Late Spring Breeding: Baluchistan. During May breeding took place in the upland areas of Sarawan (Kirdigap, Mastung, Sariab and Kalat), Loralai (Bori, Shahkarez and Gazgi) and Zhob (Hindubagh, Killa-Saifulla and Fort Sandeman). Breeding also occurred in the Bolan area at Kirta and in Chagai district (Kishingi, Shorarud, Chagai and Nushki). In Chagai, hoppers assumed wings by middle of May, while at higher elevations as in Sarawan (Mastung, Kalat), Shorarud (Panjpai), Loralai,

Zhob (Hindubagh), Quetta-Pishin (Pishin) and Sibi (Kach), locusts were still in the hopper stage till late in June. At Kach (Sibi Dt.) a few hoppers were found even in July.

Punjab. Breeding was observed in the districts of Attock, Jhelum and Gujrat in the north and Muzaffargarh and Multan in the south-west. Except in Attock and parts of Jhelum, breeding would appear to have been rather casual and of no great importance.

III. *Summer 1928:* (June-August 1928)

The flights from the west, which began at the end of April, apparently continued throughout June and July in Sind, the Punjab and Rajputana. Such records as are available show that some swarms reached the hill areas of United Provinces (Dehra Dun, Almora and Garhwal) in the third week of May and continued to be present there till July. According to a report received from the Government of Bihar and Orissa, a fairly large yellow swarm flying 20 to 25 feet above ground came into Gaya Farm from a western direction in June (data not given) and after alighting damaged *sanai, juar* and soybeans. A similar report from the Government of Central Provinces and Berar furnished the information that in the Saugor district, locusts visited Banda Tahsil on the 29th and 30th June, and the Saugor and Banda tahsils on the 4th July causing damage to young plants. At this time, there was similar damage to crops also in Damoh district. During the next week, there was a locust visitation in Rehli tahsil of Saugor. At this period (June-July) strong westerlies prevailed in the Central Provinces and in south Bihar, and these flights had passed eastwards in the direction of Bihar. There is no doubt that some, at least, of these swarms had passed through the southern districts of the United Provinces, but there is nothing on record to that effect.

Summer Breeding. None of the Bay depressions reached Sind or Baluchistan during July, August and September, and consequently there was no breeding in any of these areas. Even in the desert areas of Thar-Parkar district, where there was some rainfall, the precipitation was not sufficient to induce egg-laying. There was no breeding in the United Provinces either and in the Punjab, emergence of hoppers was observed only in two districts of East Punjab, Hissar and Jullundur. This should be correlated with defective rainfall in July and a long break of three weeks in August. In regard to Rajputana, there is very little information, but Burt and Dutt [1930], in their article on locust infestation in 1929-30, stated as follows in respect of Rajputana. "It is now known that damage from locusts occurred in Rajputana from July to September 1926". In Jaipur, locust swarms were reported in some numbers in July, August and September, but apparently there was no breeding. In Bikaner there would appear to have been fairly heavy infestation in some areas, while in Marwar, heavy "Reekhan" (hopper attack) was reported in Balotra—Barmer areas and at Pokaran, but only light infestation around Jodhpur and Phalodi. A study of the monthly rainfall in various parts of Rajputana indicates that rainfall in July and August was favourable for breeding in a region composed of the greater part of Bikaner and the north-eastern and southern Parganas of Jodhpur State (*vide* Pl. 44 Fig. 3). In Jaisalmer and the Thar area of Sind, rainfall was too defective to favour oviposition by swarms.

IV. *Autumn* 1928: (Sep.-Nov. 1928)

Except for a flight at Velpat (Lasbela State) on the 24th October (north to south) and another at Sanri in Sibi District (east to west) on 6th November, there were no records of locust activity in autumn in Baluchistan. In Sind, a few swarms were reported in September in Sukkur, Nawabshah, Hyderabad and Thar-Parkar, and in October a fair number of flights occurred mostly in the south of the Province. There were no reports in November and December. In the Punjab, there were few swarms in September and October, but in November, a small number of flights were reported from Lahore, Montgomery, Lyallpur and Mianwali. Early in December two flights occurred in Attock and Shahpur. In Rajputana, swarms from Bahawalpur passed through Jaisalmer in the direction of Marwar in October and damaged crops.

From the data available, there is no indication of any migration of locust swarms to the east or to the south in the autumn of 1928.

Summary of Events in 1928: (Pl. 46)

(1) Winter rainfall fairly good in Iran and Oman in December-January, middling in Baluchistan; light in the Punjab.

(2) No overwintered swarms in Sind and Punjab and in most parts of Baluchistan.

(3) Overwintered locusts migrated from the west into Mekran, Kharan, and Chagai, in February-March; some migrated further north or east into Afghanistan, Sarawan and Upper Baluchistan.

(4) There was early spring breeding in Mekran in February-April and to some extent also in Jhalawan and Chagai. The hoppers assumed the adult stage by middle of April and migrated east.

(5) By April flights from the west (of Iran and Oman origin) also entered Baluchistan and migrated into Sind, Upper Baluchistan, Kachhi and the Punjab by the last week of April. These spread all over the Punjab and reached the United Provinces during May.

(6) There was late spring breeding in most of the districts of Upper Baluchistan and in Sarawan, Kachhi and Chagai, which reached the adult stage by the end of May and in June, as also in five districts of the Punjab.

(7) Summer flights were in progress during June and July in Sind, Punjab and Rajputana: parts of these flights reached the United Provinces, Central Provinces (Saugor and Damoh) and the Gaya district in Bihar.

(8) As the monsoon was defective, especially during August, breeding was scanty and was confined to Hissar and Jullundur in the Punjab, parts of Bikaner and Jodhpur in the Sind-Rajputana desert.

(9) On account of scanty breeding, autumn flights were very few, being confined to parts of Sind, Punjab and Baluchistan. There was no eastward migration in autumn.

CHAPTER—II

Sub-period 1929 – 1932

YEAR—1929

A. WEATHER NOTES

I. *Winter-Spring Rainfall* 1929: (*Monthly Totals in inches*)

1928-29	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Iran							
Bushire	2·63	1·23	3·26	5·76	..	..	..
Jask	..	1·21	1·24	3·13	..	..	..
Charbar	0·11	0·47	..	1·21	..	..	..
Henjam	0·04	1·07	..	3·83	..	..	..
Seistan	..	..	0·04	0·47	0·06	..	..
Meshed	..	..	0·86	2·41	1·36	0·28	1·12
E. Arabia.							
Muscat	2·10	0·75	0·32	0·12	..	..	..
Behrein	2·76	0·78	..	0·59	0·19	..	..
Baluchistan							
Pasni	2·00	2·81	..	0·03	..	..	..
Panjgur	0·24	0·17	0·72	0·67	..	0·05	..
Turbat	0·05	0·59	..	0·11	..	..	..
Sonmiani	0·43	..	1·10	..	..	..	..
Quetta	1·18	0·86	0·69	3·15	0·05	0·26	0·01
Pishin	0·84	0·09	1·02	2·12	0·17	0·25	0·02
Chaman	0·05	0·02	0·51	4·04	0·35	0·04	..
Nushki	0·62	0·82	0·44	1·20	..	..	0·08
Kalat	0·79	0·32	0·88	1·14	..	0·19	0·20
Rindli	0·45	..	0·04	0·12	..	..	..
Sind							
Karachi	0·64	..	0·02	..	..	..	..
Jacobabad	0·04	..	0·20	0·13	..	..	0·12
N.W.F. Provinces							
Peshawar	3·20	2·81	0·67	0·65	2·18	1·13	0·05
Bannu	2·35	0·95	0·04	0·55	0·17	0·28	0·10
Punjab							
Rawalpindi	2·80	0·06	3·23	1·06	0·22	0·45	0·32
Gujrat	2·94	0·43	1·42	0·15	0·27	0·24	0·05
Lahore	1·52	0·59	0·06	0·16	0·01	0·15	0·08
Ambala	1·50	1·56	0·99	..	..	0·48	0·03
Hissar	1·35	0·46	0·88	..	..	0·69	0·32
D.G. Khan	0·80	1·00	0·09	0·03	..	0·06	0·15
United Provinces.							
Roorki	0·96	0·77	1·31	..	0·02	0·57	..
Agra	..	0·86	0·02	0·05	..	0·06	2·06

There were quite the usual number of western disturbances in the winter-spring period, but they were not productive of much rain in north-west India, except during February in Baluchistan.

II. *Monsoon Rainfall 1929:* (*Monthly Totals in inches*)

1929	May	June	July	August	September
Baluchistan					
Sonmiani	..	..	2·90	1·00	..
Bela	0·71	0·02	3·31	..	..
Rindli	..	..	2·18	2·05	..
Loralai	..	..	6·03	1·21	..
Sind					
Karachi	..	..	4·71	0·22	..
Jacobabad	0·03	..	3·87	1·56	..
Hyderabad	..	..	14·10	7·30	..
Mithi	..	..	9·35	7·39	..
Chachro	..	..	13·20	8·99	..
Rajputana					
Barmer	0·16	..	12·09	5·24	..
Jodhpur	..	0·63	3·34	6·15	0·14
Phalodi	..	0·36	3·66	1·32	0·51
Jaisalmer	0·12	..	1·96	5·05	..
Davikot	..	..	1·25	8·20	..
Bap	..	..	2·37	1·90	..
Bikaner	1·44	0·04	7·18	0·92	0·21
Nohar	0·14	0·21	2·56	5·66	..
Jaipur	0·57	2·51	9·66	7·81	2·88
Ajmer	0·89	1·37	17·15	6·81	1·29
Punjab					
Rawalpindi	0·32	2·75	9·99	18·96	0·40
Gujrat	0·08	1·52	12·04	15·28	..
Lahore	0·03	4·89	3·83	13·39	0·38
Ambala	0·14	2·47	9·64	3·45	1·00
Hissar	0·32	0·57	4·24	0·98	0·59
D.G. Khan	0·15	..	7·63	2·76	..
N.W.F. Provinces					
Peshawar	0·05	0·20	6·87	4·10	..
Bannu	0·10	0·49	2·43	2·57	0·61
United Provinces					
Roorki	..	2·76	6·30	5·59	4·27
Agra	..	2·06	4·69	31·0	0·45

II. *Monsoon Rainfall: May* 1929. Associated with the activity of the Bay monsoon in the Andaman Sea and in Burma, easterly winds prevailed in the northern parts of the Gangetic valley during the greater part of the month. Westerly winds were met with only in the southern parts.

June. The Bay monsoon extended into Assam and the Gangetic Plain on the 1st and caused the development of easterly winds. A depression advancing from Orissa caused heavy rainfall in the Central Provinces and the United Provinces between the 19th and the 24th.

July. The Bay current was active over its field throughout the month. Five depressions formed at the head of the Bay marched westwards or northwards during the month and caused excessive rainfall in

Orissa, Chota Nagpur, Central Provinces and N.W. India. Particularly heavy rainfall occurred between the 13th and the 15th July and between the 20th and the 29th July in Sind and Baluchistan.

August. Four depressions appeared at the head of the Bay, of which the third gave particularly heavy rainfall in Rajputana and Punjab between the 23rd and the 29th.

September. The monsoon receded from N. W. India after the 2nd.

B. LOCUST DATA: (Pl. 47)

I. *Winter*. 1928-1929 (December 1928-February 1929)

Except for a few swarms reported in January from Shahpur and Dera Ghazi Khan districts in West Punjab, there was no over-wintering anywhere in India.

According to Predtechensky [1935], 'Locust swarms were flying on the coast of the Hormuz Strait (Lingeh), Bunder Abbas and Minab; and in Persian Mekran, pink swarms were noticed on the Arabian Sea Coast (Jask, Chahbar). In February, oviposition occurred, but compared with the sizes of the passing swarms, the laying was small: many times less than in the spring of 1928. In February, locusts were flying in large numbers to the north'. In the Arabian area, large flights are reported to have appeared in February and March, from the direction of Arabia in the regions of Kowait and Basrah, but there is no information regarding the Oman area; there is little doubt, however, that similar large flights had entered south Persia from Oman side in January-February.

As there was fairly good rainfall in east Arabia (Muscat and Bahrein) in November and December, 1928, it is probable that breeding had occurred in the Oman areas in winter and that the pink swarms bred here had invaded the coastal areas of Persian and British Mekran in January-February.

II. *Spring* 1929: (March-May 1929)

The earliest available report of locust activity in Baluchistan is that of a swarm reaching Mastung in Sarawan from the direction of Nushki (Chagai) on the 3rd March and departing eastwards towards Dasht Thana. There are several records of flights appearing in the Chagai area from the direction of Iran during March. In this connection, it may be stated that Predtechensky [1935] mentions about flights of locusts appearing at Duzdap (Zahidan) at the end of February and about locusts flying in large numbers during February towards the north from Iranian Mekran.

On the 22nd March, flights passed over Sarawan and apparently reached the Quetta-Pishin district, where they were reported from Bostan and Khanozai of Pishin tahsil. On the 31st March locusts were passing over Jhalawan from the direction of Gidar and Kharan. Some swarms would appear to have reached Sind in March, as they were reported from Mahals Manjhand and Kohistan and Kotri Taluq in Karachi district between the 9th March and 1st April.

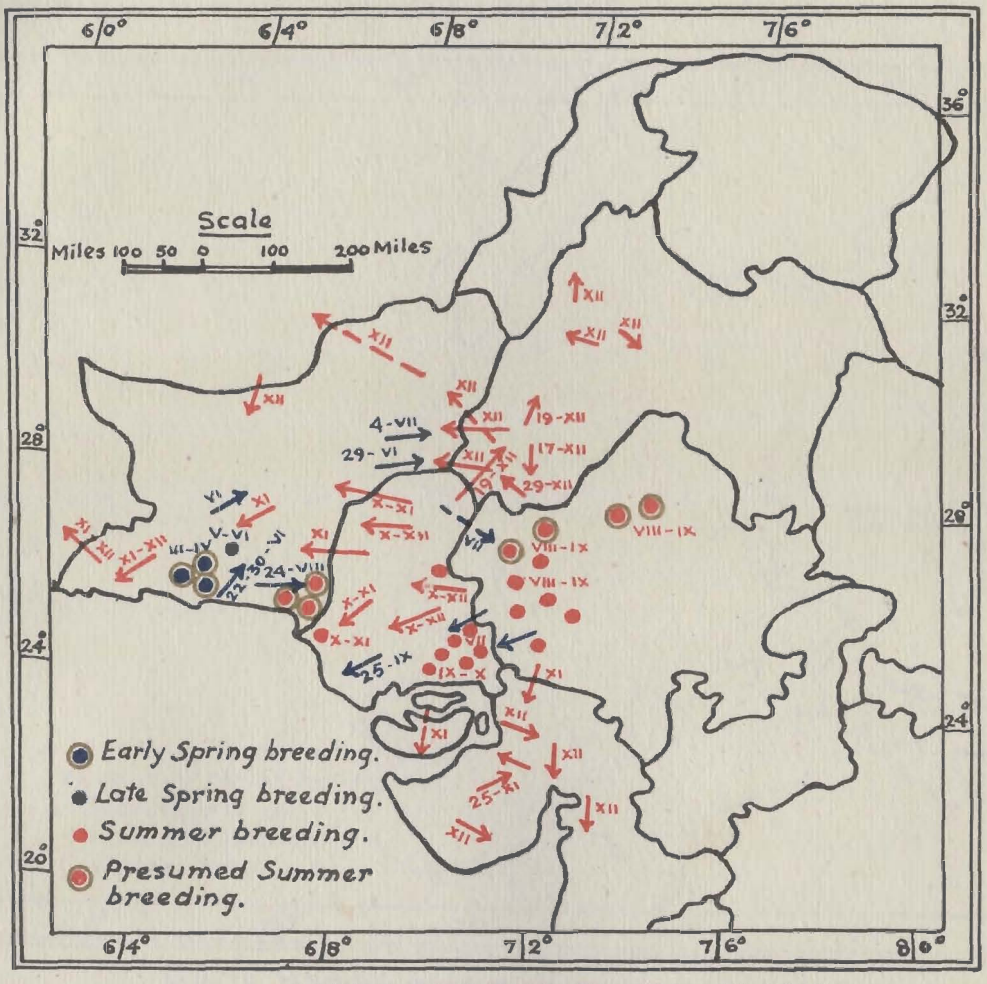


FIG. I LOCUST SITUATION IN INDIA IN 1926

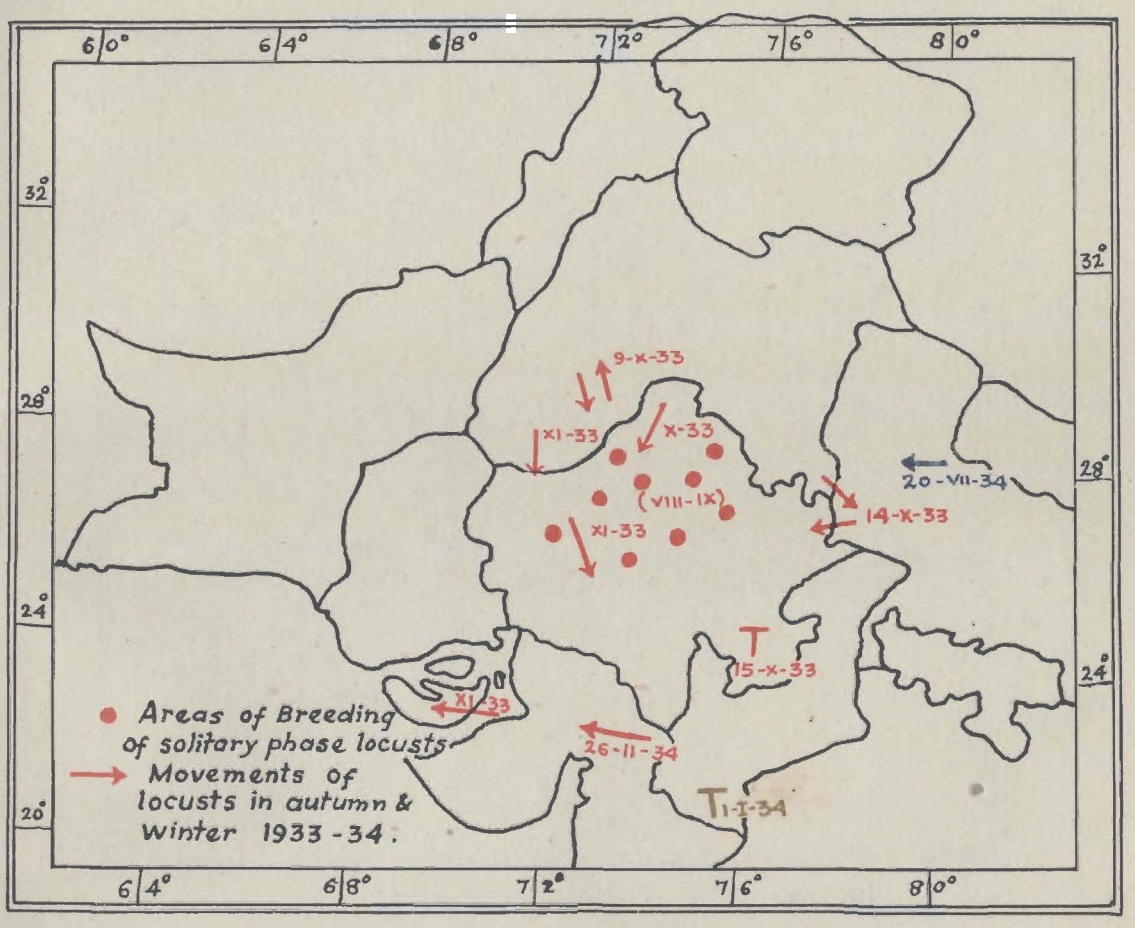


FIG. 2 LOCUST SWARM MOVEMENTS IN 1933

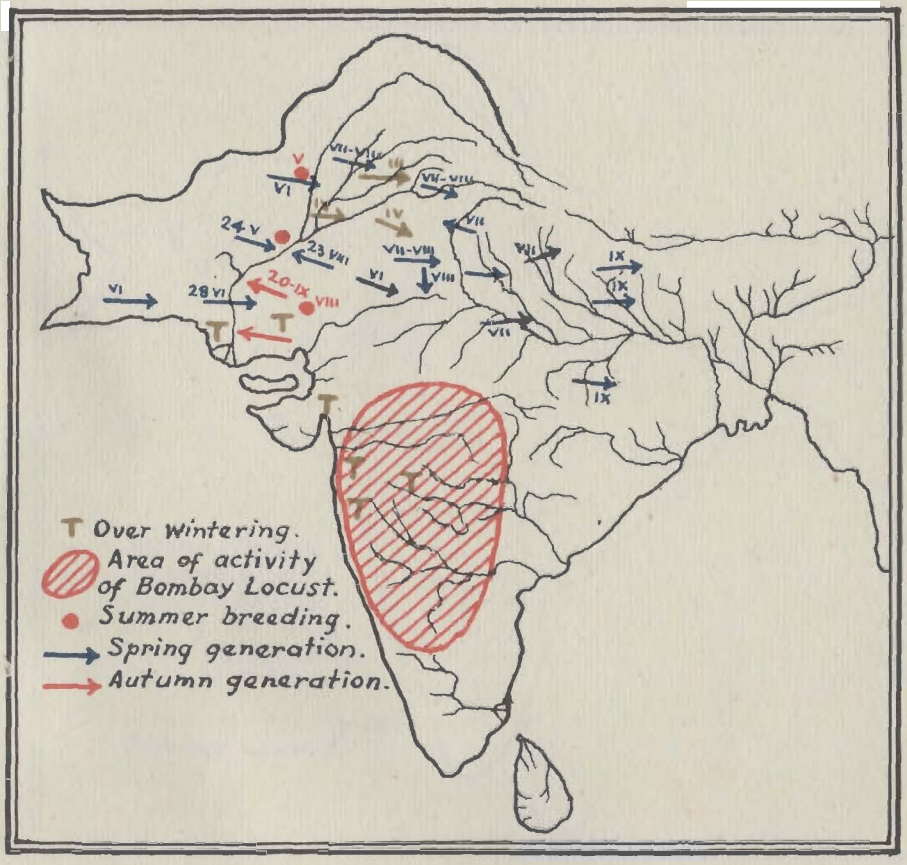


FIG. 3 LOCUST SITUATION IN INDIA IN 1904

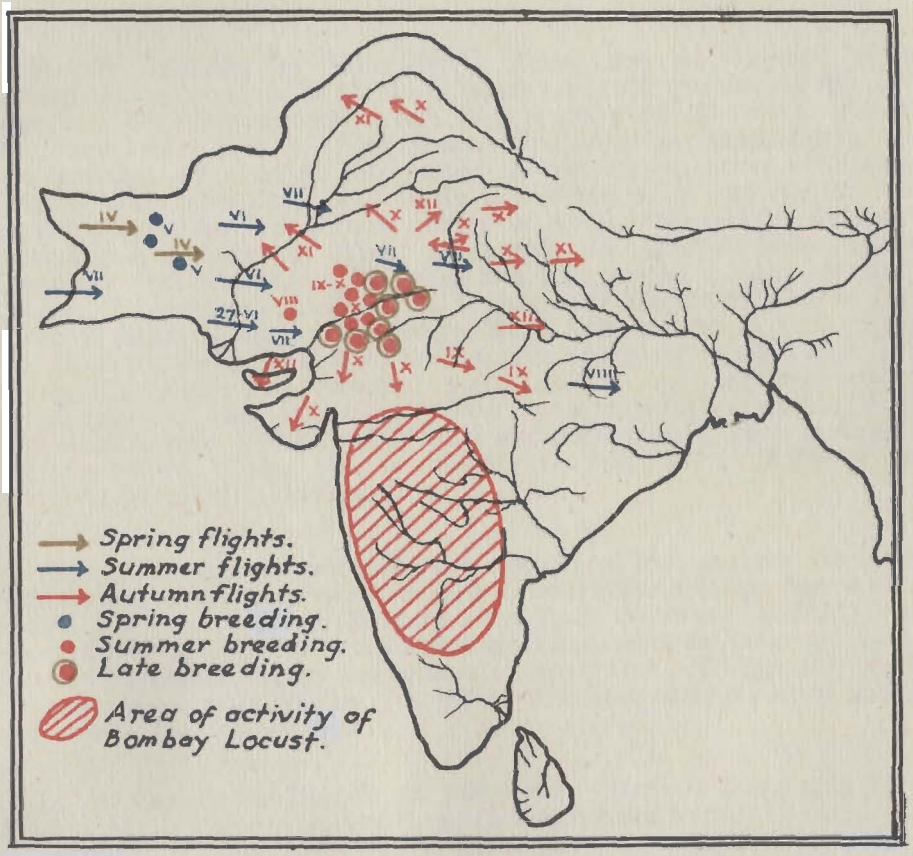


FIG. 4 LOCUST SITUATION IN INDIA IN 1905

During April, locust flights continued in great force. There were reports of numerous swarms from Mekran (Dasht, Kolwah and Panjgur), Jhalawan, Sarawan and Chagai; Kachhi; Quetta-Pishin (Pishin, Chaman and Quetta tahsils), Sibi (Shahrig, Kach); Loralai; and Zhob, during April. The date of first report for Chaman was 9-iv, for Sibi, 10-iv (Shahrigh and Harnai); and Zhob, 10-iv (Ahmadzai). At about this time, 7/10-iv, swarms were reported from Mirjawa and Ladis in Persia. In this connection, it may be noted that the earliest record of the appearance of swarms in the spring period in the Punjab is the 7th April in Dera Ghazi Khan and Multan, and that locusts entered Jhang, Shahpur and Mianwali between the 9th and 11th April, which would indicate that a wave of migration had been passing from the direction of Iran across Baluchistan into Sind and the Punjab between the middle of March and the middle of April.

Spring Breeding in Baluchistan. There are no records of any oviposition or breeding in Mekran, Jhalawan or Chagai during the spring months. This is apparently due to a scarcity of rainfall in January-February and March in these areas. On the other hand, fairly good precipitation occurred at this period in the upland areas of Sarawan, Quetta-Pishin and Zhob, and fairly heavy breeding occurred in these areas between April and June. Early in April (about 11-iv) oviposition commenced in Sarawan (Tiri, Mastung), in Quetta-Pishin (Pishin, Chaman), and Sibi (Kach, Manghi), and later in the month, occurred in Loralai (Kharashang, Sinjawi, Bori, Duki and Barkhan); Quetta-Pishin (Toba Achakzai); Zhob (Hindubagh, Killa Saifulla and Fort Sandeman) and Sibi (Shahrigh and Kach). Hoppers appeared in all these areas during May and control measures were taken by the local authorities as far as possible. The earliest date of assuming the adult stage was the 12th May in Sarawan. By the end of May and during early June, most of the hoppers became winged, but in colder areas like Toba, hoppers were being reported till middle of July.

Compared with the year 1928, the advance of locusts from the Persian borders was much more rapid in 1929, although the invasion began almost about the same time (January-February). Whereas in 1928, locusts reached the upland districts of Baluchistan, such as Sarawan, Quetta-Pishin and Zhob, only by the middle of April and laid eggs during May, swarms appeared in 1929 by the end of March or early in April and laid eggs by the middle of April.

In the case of the Punjab, in 1928 swarms arrived there only by the 22nd of April, whereas in 1929 they reached it prior to the 7th April. This is presumed to have been due to the paucity of rainfall in 1929 in the areas of Mekran, Jhalawan and Chagai, by reason of which swarms passing through them had found no incentive for protracting their halt there, in view of the absence of vegetation for feeding and lack of soil moisture for egg-laying, and had presumably been led to advance along the usual migration routes at a more rapid pace than usual. In this connection the remarks of the Tahsildar of Nushki (Chagai District) in his report dated 6th April 1929 are of much significance: "No eggs can be laid as the land is dry on account of scarcity of rain and the prevalence of sand storms. The soil has become hard and the temperature is high". It was only when the flights reached the upland areas, where there had been better rainfall, that locusts could find conditions conducive to egg-laying.

An examination of the temperature records of some of these areas; Mirjawa, Dalbandin, Quetta, Fort Sandeman and Multan for the last week of March and the first week of April has shown that the mean temperatures were higher comparatively in 1929 than in 1928, and the mean relative humidity lower. Predtechensky [1935] has also recorded that in the Persian areas, the advance of the yellow locust from the coast to the Khorasan areas was earlier by about 10 to 20 days in 1929 than in 1930, and that the temperature was higher in 1929. Available rainfall records for Persia indicate that in February 1929 there was little rainfall in Charbar, as was also the case in the adjoining areas of British Mekran, whereas at Jask and in areas to the west, good rainfall had occurred. This would indicate that in the areas of Eastern Persian Mekran and Baluchistan there was a lack of spring rainfall as in the adjoining British areas of Mekran, Kharan, Jhalawan and Chagai and this might possibly have been the cause of the earlier appearance and the more rapid advance of the spring invasion of the yellów locust in Persia in 1929 than in 1928 and 1930.

In March-April some flights are recorded as having passed on towards north or north-west into the Afghanistan areas (Shorawak and Garmsel) from Chagai.

Spring Flights. The flights that reached Multan and Dera Ghazi Khan on the 7th April, and Mianwali on the 11th, spread over most parts of the Punjab in the course of April and the early part of May. Towards the north, Attock and Rawalpindi were reached on 17-20/iv and to the east, Ambala and Karnal by 19-20/iv. Apparently some swarms flew further east into the United Provinces, being reported from Garhwal on the 25th and Dehra Dun on the 27th April. In the Punjab, flights were reported about this time also from hill areas, as at Simla on the 28th and Kangra on the 29th.

There are no data for the North West Frontier Province for this period, but since the flights in Mianwali and Shahpur on the 10th April and Attock on 17—20/iv had evidently been derived from Baluchistan areas (Zhob and Loralai districts), there is little doubt that they had come by way of Dera Ismail Khan and Kohat districts.

Spring Breeding in the Punjab. Owing to defective spring rainfall there was only sporadic and light breeding in the Punjab. It was only in the Attock district that breeding was fairly heavy and control measures were taken against the hoppers. Only light breeding apparently occurred (if at all) in other places: Multan (eggs reported laid on 8th April): Shahpur (stray hoppers seen on 18th April); Jhang (eggs reported laid on the 27th April); Kotkhai near Simla (eggs reported laid on 9th May).

In Attock, the hoppers would appear to have assumed wings by the middle of June.

III. *Summer* 1929:—(June to August)

Late Spring Breeding. As already mentioned, hoppers were found in the upland areas of Baluchistan throughout June and some even in July. Most of the hoppers became adult towards the end of May and during June, and the young swarms began to fly towards the east in June.

Summer Flights. Early in June several flights of pink locusts were observed coming into Chagai from Afghanistan territory (often in association with sandstorms) and causing damage to jowar and cucurbits. At the same time swarms were also seen in various parts of Mekran, such as Panjgur, Kolwah and Kech, and in Jhalawan, Kachhi, Sarawan and Lasbela flying eastwards. Towards the last week of June, large flights were also reported from the upland areas of Quetta-Pishin, Zhob, Sibi and Loralai. In Sind, the earliest record of summer flights from the west was the 12th June at Sinjhoro, Nawabshah district, after which numerous swarms were reported during June and July. Apparently these flights had passed on into Rajputana (Marwar, Sirohi, Bhurtpore, Alwar etc.) and possibly thence into Central India. Flights also reached the Punjab in June and July from the west and spread all over the Punjab. Apparently many of these swarms passed on into the United Provinces during June and July, though there are few records. The fact that a swarm of pink locusts was seen at Nawada (Gaya Dt.) in Bihar coming from the North-west at the beginning of June would indicate that it had come from the direction of the United Provinces in the course of May and June. Records of flights in Malia Taluk (west Kathiawar) on the 28th June and in Morvi and Dhrangadhra States on the 29th June would show that the western flights had reached the western India States by the end of June from the direction of Sind.

As to the origin of these flights there is little doubt that those reported from Chagai in June were referable to swarms bred in Afghanistan and Seistan areas situated to the north and north-west, and those found in Mekran and Jhalawan were probably from Persian areas (Kerman and Laristan) situated to the north and west of Jask and Bunder Abbas, where rain had fallen in spring. Some of the flights appearing in the Punjab and Sind were undoubtedly composed of swarms bred in the upland areas of British Baluchistan. The later flights, reaching the Indian areas in August were probably those produced in more distant places, such as the more northern areas of Persia like Khorasan and possibly Soviet Turkmenistan.

Summer Breeding. As already stated, the monsoon gave heavy rainfall in most parts of northern India especially in Sind, Baluchistan and Punjab in July and August in the course of the progress of depressions from the Bay of Bengal. In July, there was extraordinarily heavy rainfall in many parts of Sind and Rajputana especially in the region composed of Hyderabad and Thar-Parkar of Sind, and Sheo and Mallani Parganas of Jodhpur State. Rainfall extended into the eastern part of Baluchistan such as Loralai and Sibi districts and the Kachhi, Jhalawan and Lasbela areas. As there were large numbers of locust swarms roaming about in these areas heavy egg-laying took place there. The rainfall in August was also heavy, especially in the northern parts of Sind and in many parts of the Sind-Rajputana desert, so that breeding continued without a break in Sind and Rajputana during these months.

In the Punjab and the United Provinces also rainfall was equally favourable for heavy multiplication and breeding occurred in 23 out of the 29 districts of the Punjab and in the United Provinces—where summer breeding had not taken place for quite a large number of years prior to 1929—hopper bands were encountered in as many as 14 districts.

Baluchistan. Locust swarms were reported entering parts of Loralai, Sibi, Kachhi, Jhalawan and Lasbela districts from the east at the time of the advance of the depressions in the latter half of July and during August. With the occurrence of rainfall, eggs were laid in most of these areas during August and September.

In Lasbela, breeding occurred in the Habnadi, Uthal and Liari areas, in Loralai district, hoppers were found in Barkhan, Bori and Duki tahsils and breeding also occurred in the Marri and Bugti tribal areas; in Sibi district, infestation was reported from Kohlu tashil, from Dirghi in Harnai tahsil; from Sibi and Nasirabad tahsils; in Zhob district, from Killa Saifulla; in Jhalawan, from Karkh and Zedi; and in Kachhi, from Lahri, Bhag, Gandhawa, Dadhar, Mashkaf and Mirpur-Nasirabad. Hoppers were found in numbers even in October in Kachhi and in the Nasirabad tahsil, and a few survived even till November.

Sind. In most years locusts breed only in the desert areas of Sind, but the infestation in 1929 was peculiar in the circumstance that it was spread all over the province. In the words of the Dy. Director of Agriculture, in his report on the Anti-Locust Campaign of 1929 in Sind, "The locust invasion of the year is unique in its character inasmuch as eggs were laid in Sind proper, in cultivated fields, mounds and all sorts of ground all over the province, instead of in the sandy desert of Thar-Parkar and Kohistan and visiting Sindh in the flying stage as usual. The hoppers, hatching out, marched out in solid columns in search of food, attacking bushes, grasses, crops and trees, and they could be seen everywhere, on the roads, fields, railway lines, maidans, embankments, on running-water courses mounds and sand hills, in lengths of over a mile."

The earliest reports of egg-laying were from Nawabshah district (Shahdadpur) on 15th July and from Thar-Parkar district (Chachro) on the 16th July. Eggs laid on the 17th July at Chachro are reported to have hatched on the 1st August. In Thar-Parkar district flights appeared from the east in July-August, and laid eggs all over the desert (Chachro, Diplo, Mithi, Nagar-Parkar, Umerkote, Sanghar, Ranahu and Khipro). During August and September, oviposition and breeding were observed in all districts of Sind, Karachi, Hyderabad, Thar-Parkar, Nawabshah, Sukkur, Larkana and Upper Sind Frontier; hoppers were found all over Sind during September and most of October and organized control measures were undertaken by the Sind administration with a fair degree of success.

The Punjab. In July, flights were recorded in almost all the districts of the Punjab, including the hill districts of Simla and Kangra. With the fall of good rains, oviposition commenced at the end of the month. The earliest record of breeding is from Multan on the 17th July, when hopper emergence was reported, indicating that eggs had been laid at least 2 weeks earlier. During August, egg-laying was general almost all over the Punjab. Breeding occurred in the following 23 districts during July-August: Multan, Muzaffargarh and D. G. Khan, Ferozepur, Hissar, Gurgaon, Rohtak and Karnal; Attock, Shahpur, Rawalpindi, Gujrat, Jhelum and Mianwali; Gurdaspur, Hoshiarpur, Gujaranwala, Ludhiana, Ambala and Sialkot; Lyallpur, Jhang and Sheikhupura. During August the direction of flight was definitely east to west during the periods of activity of depressions, *e.g.*, during the second week and between the 20th and the 29th. Energetic control measures were in progress against the hoppers in August, September and October. The majority of the hoppers assumed the adult stage by the end of October.

In the south-eastern districts of the Punjab, few hoppers were seen after September there being no late breeding presumably on account of the shortage of rainfall; on the other hand, in the northern and western districts, breeding continued right into the middle of November. Some hoppers were found even on 2nd December in Shahpur district.

There is little information available for the N. W. F. Province, but breeding is likely to have taken place in September-October in some of the districts, as in the case of the neighbouring parts of the Punjab.

The United Provinces. In July, there are records of locust damage only from six districts: Aligarh, Meerut, Muttra, Pilibhit, and Bara Banki (20-vii) and Fyzabad (W.E. 13-vii) indicating the presence of swarms as far east as 83° E. Long. It is probable they occurred even further east, without being reported. As easterly winds were prevalent throughout the month, swarms were probably drifting westwards in most parts of the province, leading to a concentration of swarms in eastern Punjab and western United Provinces. Oviposition probably commenced at the end of July and continued throughout August and up to the 3rd week of September. According to Richards [1931], locust swarms 'bred in seventeen districts from Saharanpur and Bijnor in the north to Lucknow and Bara Banki southwards.' It is, however, evident from the Administration Report of the Department of Agriculture, United Provinces for 1929-30, that 18 districts (inclusive of Allahabad) had been affected in 1929, so that hopper infestation extended further east up to Allahabad. The main area where breeding occurred is situated in the western half of the Province, lying to the west of the line Bara Banki—Lucknow—Unao—Cawnpore. It is rather remarkable that most of the districts affected: Saharanpur, Muzaffarnagar, Agra, Meerut, Bulandshahr, Muttra, Aligarh, Etah, Mainpuri, Etawah and Cawnpore (and Allahabad), lie within the Jumna-Ganges Dôab, the rest (Bijnor, Moradabad, Budaon, Unao, Lucknow and Bara Banki) being situated in a region just east of the Ganges. "The extent to which breeding took place in these districts varied, being most concentrated between Meerut and Agra." The damage done by hoppers was apparently "very serious, large areas of the worst attacked districts being completely devastated." [Richards 1931 p. 161].

Hoppers were reported throughout August and September and during part of October. In a few districts, however, hopper infestation continued even in November: Etah, Bijnor and Muzaffarnagar, large numbers of hoppers being said to occur "in over 100 villages" during November, apparently indicating late breeding in this area. In a letter dated 18th November, from the Collector reporting a swarm at Sikandarpur in Ballia district (in the extreme east of the province) it was mentioned that "some eggs had been found", but possibly the information may not have been correct.

The Rajputana Areas.—As in 1927 and 1928, the data for Rajputana for 1929 are far from complete. The scanty information available indicates that swarms entered the area in June and July and oviposition had occurred in Bhurtpore, Alwar, Sirohi and parts of Marwar, Jaipur, and Bikaner resulting in the emergence of "phaka" or hoppers in August. A study of the rainfall data indicated that there was little rain in June, that good and continuous rainfall occurred in July and August and that September was dry in most places (*vide* Pl. 44, Fig. 4). The distribution of rainfall in July and August was not uniform. In July, fairly good rainfall had fallen all over the Sind-Raputana desert except in Jaisalmer, and very heavy rain in Thar-Parkar and Mallani. In August, rainfall was light in Bikaner and east Jaisalmer and north Marwar, but fairly heavy elsewhere. There was heavy breeding in the Thar area of Sind, in Sirohi, and in most parts of south Marwar, Merta downwards including Sojat, Bali, Desuri and Jaitaran, and light breeding in Phalodi and other parts of Marwar. In Bikaner, ravages of

locusts are said to have 'aggravated the hardships due to drought (in August)'. Presumably hoppers were present throughout August and September and assumed the adult stage during September-October.

IV. *Autumn 1929.*—(September-November 1929)

As already stated, locusts were present in the hopper stage throughout September and October in most parts where breeding had been observed. Measures of destruction were organized in most areas: especially in Sind, the Punjab and the United Provinces, but Richards estimated that in the United Provinces, "no more than 75 per cent. of the resultant hoppers were destroyed in spite of an energetic campaign against them." [Richards 1931]. In many areas, however, in Rajputana especially, quite a large proportion of the hoppers had assumed wings and formed swarms which began to roam the country during October and November and attack crops.

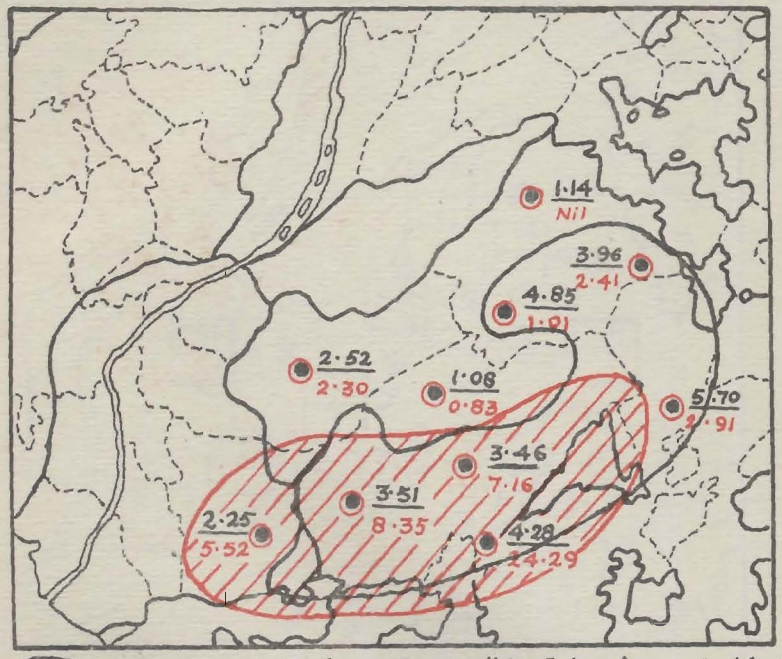
Autumn Flights. (1) From the middle of September fliers of the new generation were noticeable in *Sind.* In September, the direction of their flight was variable, but in October-November, the general direction was from the east or north-east from the Rajputana area to the west or south-west towards Baluchistan side. These swarms—mostly composed of pink locusts—were often destructive to the standing crops of Bajri, Jowar or Cotton.

(2) In *Baluchistan,* numerous flights were reported passing in a westward direction over Lasbela, Jhalawan, Mekran (Turbat, Hoshab, Kulanch, Tump, Pasni, Dasht, etc.) and Loralai district. Some of the swarms found in Lasbela and Mekran areas were said to have been of enormous dimensions and large masses of locusts were reported to have been washed ashore along the beaches between Ormara and Pasni in November-December 1929. This circumstance may be considered as fairly positive evidence that numerous swarms had been crossing the Gulf of Oman in the direction of the Oman Coast. Presumably many swarms had similarly passed into Iranian Mekran during winter.

(3) In the *Punjab,* hoppers were assuming wings in the course of September and October and were forming swarms, which were active all over the province during these months. The majority of the swarms were passing out of the Punjab towards the east or the south-east into the United Provinces or Central India. In November and December, very few swarms were noticeable in the south-eastern districts:—Ferozepur, Hissar, Rohtak, Karnal and Gurgaon, but numerous swarms were active in the northern and western parts of the Punjab, generally flying westwards or northwards, in the direction of the N. W. Frontier Provinces and Baluchistan. Many flights also reached the foot hills of the Himalayas in the Simla, Kangra, Sialkot, Rawalpindi and Gujrat districts.

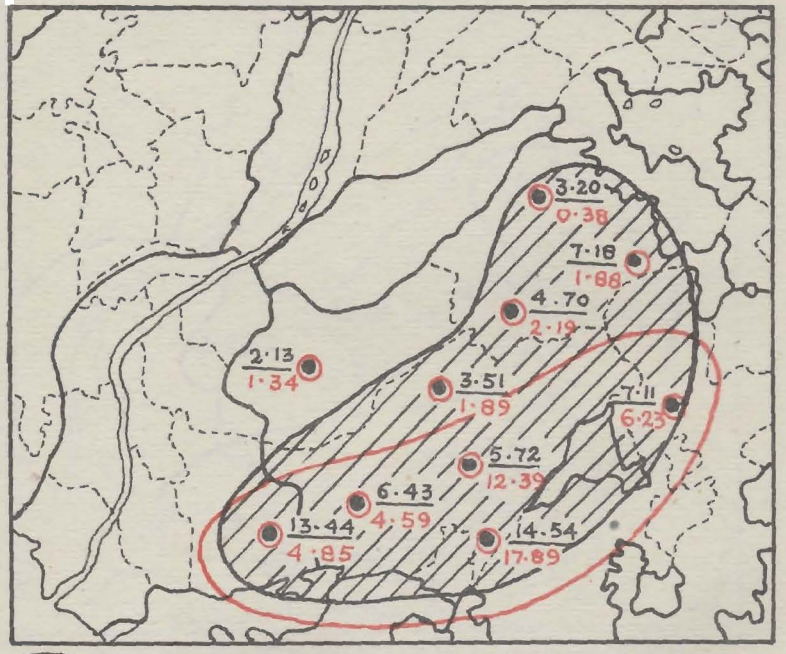
(4) In the *United Provinces,* locust swarms were found in comparatively small numbers during September. From the middle of September, flights gradually increased and were directed generally towards the east, north-east or south-east. During October, swarm movements were general all over the province, the direction being mostly west to east or north-west to south-east, and had reached by the last week of the month as far east as Gorakhpur and Ghazipur. Early in November, swarms were reported from most of the eastern districts including Gorakhpur, Ballia, and Mirzapur, and as it is recorded that a swarm had visited the Pusa Estate in Bihar on the 7th November and departed northwards in

FIG. 1 SIND-RAJPUTANA
SUMMER BREEDING AREAS-1926



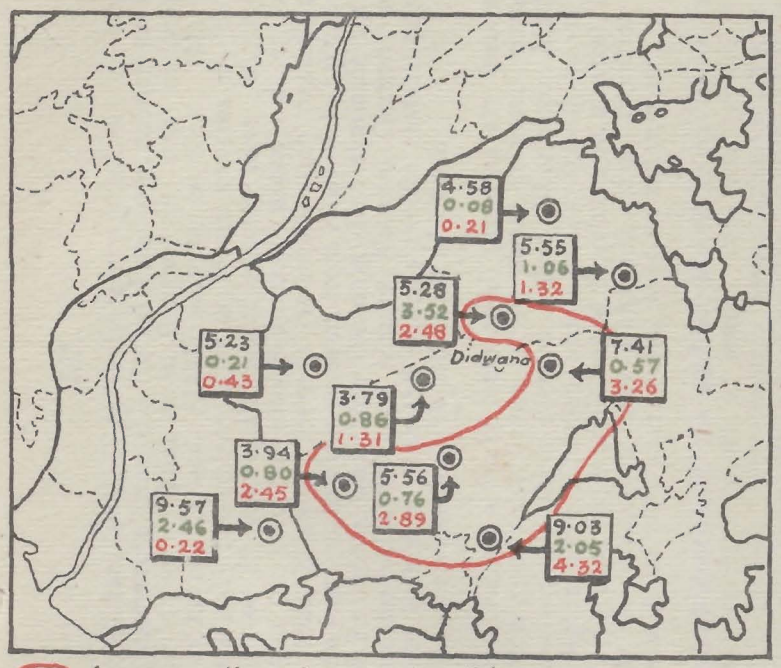
Limit of satisfactory Rainfall in July shown in black.
Area of heavy Rainfall in September shown in red.
3·96 / 7·58 Rainfall in inches with station
(Good rainfall in August every where)

FIG. 2 SIND-RAJPUTANA
SUMMER BREEDING AREAS-1927



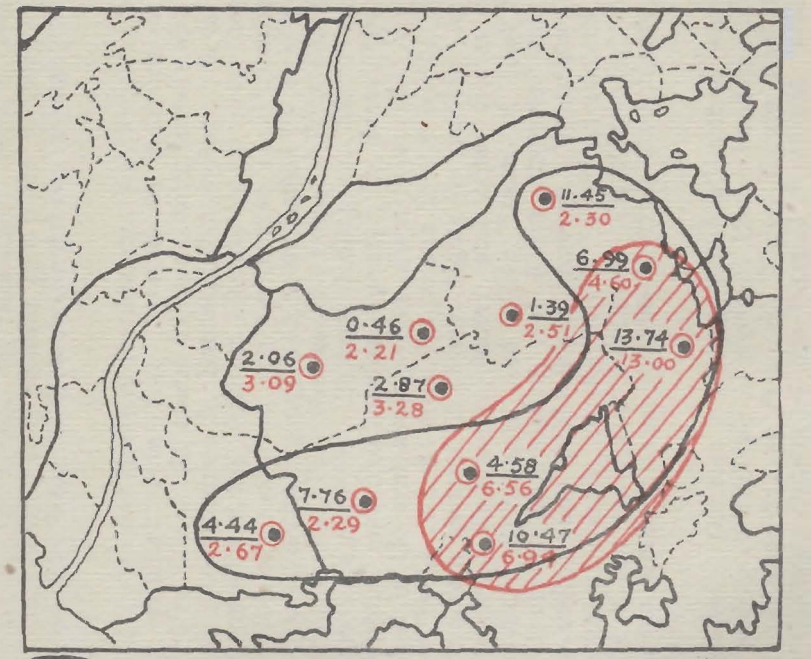
Limit of good rainfall in July shown in black.
Limit of good rainfall in August shown in red.
3·20 / 0·38 Rainfall in inches with station.

FIG. 3 SIND-RAJPUTANA
DESERT AREAS-1935



Area of satisfactory rainfall in September
Rainfall Station. Rainfall figures are shown in inches
Rainfall in July: in Black.
Rainfall in August: in Green (August rainfall poor in most places)
Rainfall in September: in Red

FIG. 4 SIND-RAJPUTANA
SUMMER BREEDING AREAS -1912



Limit of good rainfall in July shown in black
Limit of good rainfall in August shown in red
11·45 / 2·30 Rainfall in inches with station
(Very little rain in September)

the afternoon, [Isaac, 1931], it is likely that several similar other flights had travelled eastwards from the United Provinces, though there are no records of any either in Bihar or in Bengal. In this connection, the following remarks of Richards [1931] may be recalled: "Many reports have been received (November 1929) of locust swarms in the extreme east of the United Provinces, and some swarms have already passed eastwards out of the province into Bihar and Orissa." After the middle of November 1929, however, there is no information regarding swarms either from the eastern districts or even from most of the plains districts of the United Provinces, and since the only data available for the province are from the hill districts of Almora, Nainital, Garhwal and Dehra Dun, it may be presumed that the swarms in the eastern parts of the province had likewise reached the hill areas of Nepal.

(5) In *Rajputana*, as already mentioned, the data are incomplete. In September-October, swarms began to fly about in most parts of Rajputana. In the eastern parts, such as Jaipur, Bhurtpore, Alwar, Kotah and Mewar, flights were reported which would appear to have passed eastwards into Central India and Central Provinces in general, but sometimes towards the south. In west Rajputana, the direction of flight would appear to have been south-west, west or north-west.

(6) In *Central Provinces*, the earliest record is for week ending 7-x for Damoh district, flight north to south. The next record is that of week ending 21 October, when swarms passed through Nimar district, presumably towards the south into Khandesh district (Bombay). Towards the last week of October several swarms visited the districts of Damoh and Jubbulpore (and during November) Saugor, Jubbulpore Damoh, Narsinghpur, and Seoni. In December, certain swarms were found in Betul and Seoni. It is possible that some of these swarms had passed eastwards into Bihar in October-November, though there are no records of flights.

(7) *W. India States and Bombay Presidency*. In the States of Western India Agency, swarms were first reported in autumn on the 15th September in Wao State. At about the same time locusts also appeared in Suigam and Deodar areas in Banaskantha Agency. It is presumed that they had come from the southern Marwar areas where heavy breeding is known to have occurred. In the course of September, several places in the Banaskantha Agency had been visited by swarms; Tharad, Deodar, Kankrej, Varahi, Tara etc., as also areas in Palanpur, Wadhwan, Dasada, Bajana, Dhrangadhra, Rajkot, Radhanpur, Morvi etc., and in Ahmedabad district and Mahikantha Agency. In September northerly winds developed in Gujerat areas, which were presumably concerned in the transfer of flying swarms from Rajputana to the south. In October there were numerous reports of swarm flights in various localities in Banaskantha Agency, Radhanpur, Morvi and other States of western Kathiawar Agency; Bhavnagar and other States of East Kathiawar Agency in Rajkot; in Ahmedabad and Kaira districts; and in Panch Mahals, Rewakantha and Mahikantha Agency. Doubtless there was locust infestation in Baroda territory also, though no records are available except for a few reports in November. In November and December also, swarms were reported in these areas though apparently in smaller numbers.

In the *Presidency Division Proper of Bombay*, swarms were reported during week ending 26 October in parts of East Khandesh, West Khandesh, Nasik and Ahmednagar districts. These flights had apparently come from the Nimar district of the Central Provinces, where locusts

had appeared from the north during week ending 21st October. A study of the meteorological data recorded in the Daily Weather Reports has shown that winds in the Nimar-Khandesh area were northerly or north-easterly from the 8th October to the end of the month, and had helped to transfer the swarms from Nimar into Khandesh, Nasik and Ahmednagar and possibly also into Aurangabad district of Hyderabad State. During November with the development of easterly winds, locusts had apparently been carried further west into Thana, Broach and Surat.

Summary of Events in 1929: (Pl. 47)

(1) Winter-spring rainfall was fairly good in south-western Iran and in Oman, but was very defective in Mekran, Chagai, and Jhalawan; it was fair in Upper Baluchistan but rather defective in the Punjab.

(2) There were practically no over-wintering swarms anywhere in the Indian areas. Locusts appeared in February-March in Mekran and Chagai, but owing to the drought prevailing there, they flew on northwards into Afghanistan and north-eastwards into Upper Baluchistan and thence reached the Punjab early in April. Flights also passed over Jhalawan into Sind and Kachhi at about the same time.

(3) Extensive egg-laying occurred in April-May in Upper Baluchistan where conditions were favourable by reason of good spring rainfall, whereas there was no breeding anywhere in Mekran, Jhalawan, Kharan and Chagai. In the Punjab eggs were laid only in a few districts mainly in the north. Swarms, however, spread all over the Punjab, reaching hill districts such as Simla and Kangra by end of April and Garhwal in the United Provinces by May.

(4) Summer flights from the west commenced from the second week of June and were composed of swarms produced in April-May in the western parts of Iran and in parts of Upper Baluchistan. They spread over Sind, Punjab, Rajputana and the United Provinces during June and July. One flight was reported as far east as Gaya in Bihar in June.

(5) With the occurrence of heavy and continuous rainfall all over north-west India in July and August, especially in Sind and Rajputana, extensive egg-laying and breeding occurred all over Sind, in Lasbela, Kachhi and Loralai in eastern Baluchistan, in 23 districts of the Punjab, in 18 districts of the United Provinces and in most parts of Rajputana, during August, September and October. In some places hoppers were noticeable even in November.

(6) There were extensive flights in the autumn. Numerous swarms flew westwards into Sind, Baluchistan and Punjab and a great many reached the Iranian borders by October-November. Other flights passed over the United Provinces into Bihar by November and reached the foot hills of the Himalayas in Dehra Dun, Garhwal, and Almora and possibly also in Nepal territory. Some swarms reached the Central Provinces (Damoh, Saugor, Jubbulpore and Seoni) in October-November and others the Nimar district in October and thence southwards into Khandesh, Nasik, Ahmednagar, Thana and Surat in Bombay in November. In September, numerous flights passed south from southern Marwar into the Western India States, Kathiawar and Gujarat and remained active there till December.

YEAR—1930

A. Weather Notes 1930

I. *Winter-spring Rainfall* 1929-30 (*in inches*)

1929-30	Nov.	Dec.	Jan.	Feb.	Mar.	April	May.
Iran							
Bushire	2·65	6·70	6·40	0·57	0·33	..	..
Jask	0·14	1·45	5·93	..	0·82	0·04	..
Charbar	2·37	7·15	0·64	..	0·30	..	..
Henjam	3·15	2·41	..	2·67	0·27	..	..
Seistan	0·51	1·38	0·05	0·13	0·63	..	..
Meshed	0·22	..	3·39	0·75	2·69	2·37	2·[illegible]2
E. Arabia							
Muscat	1·35	4·55	5·61	0·02	0·04	0·23	..
Behrein	..	1·32	0·68	0·08	0·13	0·21	..
Baluchistan							
Pasni	0·79	5·83	2·86	..	..	..	..
Panjgur	0·15	1·95	1·99	0·07	0·37	0·91	0·01
Turbat	0·29	3·16	4·12	0·22	..	0·63	0·09
Sonmiani	0·86	1·80	0·71	..	..	..	..
Quetta	..	2·79	2·73	0·82	0·49	2·19	0·03
Chaman	..	3·62	2·52	1·19	..	3·04	..
Nushki	..	3·68	1·75	0·74	0·38	0·73	..
Kalat	0·13	2·63	1·64	0·48	0·77	1·21	0·01
Rindi	..	1·00	..	..	..	0·21	..
Sind							
Karachi	1·10	0·54	0·26	..	..	..	..
Jacobabad	.	0·89	..	..	0·06	0·03	..
N.W.F. Provinces							
Peshawar	..	1·24	1·51	0·89	1·54	3·92	0·10
Bannu	..	1·59	0·44	0·31	1·22	3·71	0·35
Punjab							
Rawalpindi	..	4·28	5·46	2·73	0·36	5·48	0·87
Gujrat	..	2·23	1·52	1·30	0·27	5·52	0·43
Lahore	..	2·27	0·60	0·20	0·03	1·36	0·40
Ambala	..	3·37	1·83	1·84	1·11	0·37	..
Hissar	0·07	0·67	0·08	0·28	0·16	0·40	..
D. G. Khan	..	0·64	0·22	..	0·09	0·43	0·25
United Provinces							
Roorki	..	3·05	3·47	4·72	..	0·75	0·25
Agra	..	0·51	0·51	0·40	..	0·02	0·16

December 1929. Of the 6 western disturbances of the month, the 3rd and 4th gave widespread rain over N. W. India during the 2nd and 3rd weeks.

January 1930. The second of the four western disturbances gave widespread rain over northwest India including east Rajputana, the Punjab, Kashmir and west United Provinces.

February. 5 western disturbances of the month gave the normal amount of rain in east and north Punjab. Rain was in large excess in western United Provinces, but was in defect in Baluchistan and Sind.

March. Rainfall more or less in defect.

April. Rainfall in excess in north-west India except in United Provinces and in large excess in east and north Punjab. N.W. Frontier Province.

May. Rainfall in defect in Punjab, United Provinces and Baluchistan, but in large excess in Rajputana.

II. *Monsoon Rainfall* 1930. (*Monthly totals in inches*)

1930	May	June	July	August	September
Baluchistan					
Sonmiani	..	0·40	4·66	..	..
Bela	1·54	0·25	2·28	..	0·03
Rindili	..	1·56	5·30	..	..
Loralai	0·29	..	2·25	0·32	..
Sind					
Karachi	..	2·00	12·48	0·01	..
Jsbabad	..	3·35	2·36	..	..
Mithi	.	1·70	1·26	0·05	0·84
Chacrho	.	0·82	2·32	0·30	0·82
Rajputana					
Barmer	0·59	0·61	1·22	..	0·58
Jodhpur	0·75	2·23	2·97	1·84	0·28
Ahialodi	0·25	2·11	0·43	0·58	0·28
Jacsalmer	0·43	0·91	0·57	0·77	..
Davikot	..	0·69	1·55	0·20	..
Bip	.	0·15	0·35	1·42	..
Bikaner	1·19	2·61	3·25	1·42	..
Nohar	0·46	4·33	9·48	1·73	..
Jaipur	1·88	5·39	7·63	5·06	0·24
Ajmer	2·58	5·29	2·69	7·98	..
Punjab					
Rawalpindi	0·37	1·13	17·83	8·73	3·38
Gujrat	0·42	0·85	9·45	4·73	3·80
Lahore	0·40	0·61	9·88	1·63	0 98
Ambala	..	6·77	24·66	8·95	2·09
Hissa	..	3 32	18·83	3·41	1·30
D. G. Khan	0·25	0 19	6·93	..	..
N. W. F. Provinces					
Peshawar	0·19	..	3 35	0·13	1.64
Bannu	0·35	0·55	0·03	0·33	1·20
United Provinces					
Roorki	0·25	3·86	14·95	5.29	1.85
Agra	0.10	4·39	15·25	8·12	1.98

Monsoon 1930.

June. The Bay monsoon was normally active from Burma to Bengal during the month, and extended feebly into Bihar and Orissa in the third week. It was particularly vigorous in Gujarat during the last 10 days in connection with two depressions formed off Kathiawar Coast, and as a result there was excess of rainfall in Sind and South Rajputana.

July. Three depressions formed at the head of the Bay and travelled westwards and northwards across the country. The monsoon was active over most parts of N. W. India, particularly in Sind and the Punjab. The rainfall was on the whole in excess in most parts of N. W. India.

August. In the Peninsula, a general break in the rains set in on the 7th and extended over N.W. India by the 13th. Rainfall was in slight defect in the United Provinces and in east and north Punjab, and in large defect elsewhere.

September. There was a general revival of rainfall during the early part of the month and the monsoon withdraw from north-west India in the 3rd week.

B. LOCUST DATA 1930: (PL. 48)

I. *Winter 1929-1930*: (Dec. 29-Feb. 30)

Overwintering swarms were noted in Baluchistan, Sind, Punjab and Western India States (Cutch, Kathiawar, Palanpur, Bhavnagar etc.). A few were reported from the hill districts of the United Provinces and some were also found in parts of Rajputana, (Jaipur and Bhurtpur) in January-February.

Baluchistan. Swarms were observed in many places in Mekran Jhalawan, Kachhi and Ormara during December-January, as also in parts of Sibi and Loralai districts mostly at lower elevations (such as Harnai and Barkhan).

In February, swarms were, in addition, reported from parts of Quetta-Pishin, Chagai and Zhob districts. In Mekran, swarm movements from beyond the Persian borders were noticed during January-February, and as a result of good winter rainfall, egg-laying commenced early in February in various parts of Mekran: Dasht, Tump, Panjgur (Sohrap) and also in parts of Kharan.

Punjab. Swarms were active in January and February in most parts of the province, the general direction being east to west. As the amount of rainfall in December and January was quite large in most parts of the Punjab, conditions were apparently favourable for egg-laying, and oviposition was reported from the 1st week of February in 15 districts: Attock, Rawalpindi and Jhelum in the north; Gujrat, Gujranwala, Lyallpur, Sheikhupura and Montgomery in the centre. Muzaffargarh, Multan and Ferozepur in the south, and Sialkot, Jullundur, Hoshiarpur, and Ambala in the sub-montane and eastern areas.

United Provinces. During January, flights were confined to the hill districts of Dehra Dun, Almora, and Garhwal and the Tehri State and were generally east to west, but it is very likely that some swarms were present in the neighbouring hill areas of Nepal, though there are no records.

In February, swarms were found moving from the Punjab eastwards into many parts of the United Provinces, flights being reported from Sudaon, Bijnor, Pilibhit, Bareilly, Kheri, Etah, Mainpuri, Farukhabad,

Meerut, Muzaffarnagar, Bulandshahr, Saharanpur, Ninital and Almora Eggs were laid in Saharanpur. Almora, Bijnor, Bulandshahr and Meerut.

Sind. Swarms were reported from most parts of Sind, generally flying east to west with considerable damage to crops.

Rajputana. Swarms passed through Jaipur in January and Bhurtpur in February.

W. I. States. In January, swarms were observed in Bagasra, Kathiawar, Cutch, Palanpur and Bhavnagar.

Extra-Indian areas. According to Predtechensky, yellow locusts migrated from the south into north and north-east *Persia* from February onwards up to May-June and reached as far as northern Khorasan. Oviposition occurred in Mekran (February), Baluchistan (March), Seistan and south Khorasan (April), and north Khorasan (May). In the *Arabian* area, over wintering swarms were found in large number in south *Iraq* in December 1929. Fresh swarms arrived in January-February and March from Saudi Arabia from the direction of Koweit. Oviposition occurred in Iraq from February onwards and the new generation migrated north-eastwards into Persia [Uvarov 1933].

In the Arabian-Sudanese region, there were heavy flights in Syria, Palestine, Trans-Jordania and Egypt in winter and spring and eggs were laid in the Sinai Peninsula and Trans-Jordania in February. Heavy flights were reported from all these areas during summer.

II. *Spring-1930.* (March-May 1930)

Spring Breeding in Baluchistan. Entry of yellow locust swarms from the Iranian areas continued in March and April in Mekran, Kharan and Chagai. On the 14th March, flights from Bahu area in Persian Mekran came into Gabd and passed over Kulanch areas. After laying eggs in suitable areas, swarms pursued their course into Lasbela and Jhalawan in the south and into Sarawan, Shorawak (Afghanistan), Shorarud and Quetta-Pishin. Many over-wintered flights also passed from north Sind into Kachhi, Bolan, and Sibi areas. Other passed from the Punjab into the Loralai and Zhob districts.

There was very intensive breeding between February and April over an extensive area of Mekran covering Kulanch and Dasht in the south; Tump and Mand in the Kech valley; Kilkaur, Buleda and the Gar-Parom-Shahbaz areas of Panjgur. Breeding also occurred subsequently in April in parts of Chagai; and in May, in Panjpai (Shorarud), in parts of Sarawan, in Chaman (Quetta-Pishin), Hindubagh (Zhob) and in Surab (Jhalawan); hoppers also appeared in Bhag Niabat in Kachhi in May-June.

Most of the hoppers in the Mekran areas assumed wings during the latter half of April and began to fly by the beginning of May. Many swarms took a northern or north-eastern direction and entered Chagai, Jhalawan and Sarawan. Some apparently took a southern direction early in May towards Jiwani and large numbers are said to have been drowned in the sea. Hoppers in the upland areas became adult somewhat later in May-June.

Breeding in the Punjab and United Provinces

Punjab. Hoppers began to emerge during March, but egg-laying and emergence continued throughout March, April and May, and most of the districts were affected, the only exception being Simla, Kangra, Hissar

and Rohtak, Egg-laying occurred in Gurgaon later than in others in the last week of April.

Breeding was also observed in most of the states of the Punjab such as Patiala, Jind, Sirmur etc. Strenuous efforts were made to destroy the hoppers in most parts of the Punjab, and the hoppers that escaped destruction began to assume wings in the latter half of April. The earliest report of the starting of flights by the new adults is from Hoshiarpur on the 22nd April.

During the latter part of May, there were apparently large numbers of fliers of the new generation bred in the Punjab and United Provinces which were joined by swarms of Baluchistan and Persian origin coming from the direction of Sind and Baluchistan. The general direction of flight of these swarms was either west to east or north-west to south-east.

United Provinces. Swarms were found active in the western half of the United Provinces during March and April. Egg-laying occurred in the hill districts of Dehra Dun, Almora and Garhwal, and in Almora, it was reported that eggs had been laid in the thick layers of fallen pine (*chir*) needles, as there was no loose soil in these forest areas. In Dehra Dun and Garhwal, hoppers were found in large numbers in forests.

On the plains, breeding occurred mostly in districts bordering the eastern parts of the Punjab: Saharanpur, Muzaffarnagar, Meerut, Bulandshahr, Muttra, Aligarh, Bijnor, Moradabad, Budaun and Etah. Egglaying occurred in extensive areas in all these districts. In the Aligarh district, for instance, oviposition is reported to have taken place in an area 18 miles long by 5 miles broad on either side of the lower Ganges Canal from Narora down to Etah border. Similar extensive egglaying would appear to have occurred in March 1879 on either side of the Anupshahr branch of the Ganges canal in Meerut district. In Etah district, eggs were reported by the Collector 'to have been found in the dry sides of the Ganges river and its banks almost in continuation'.

According to the report on the Administration of United Provinces Agricultural Department for 1930. 'The first reports of swarms pairing and egg-laying were received in the Bijnor and Muzaffarnagar districts on February 17, in Saharanpur and Meerut on February 24 and 26, and thereafter, Moradabad, Budaun, Bulandshahr, Etah and Aligarh areas became infested between March 3 and 23. Finally early in April, some villages in the Muttra district became infested. The districts most seriously affected were Bijnor, Meerut, Moradabad and Bulandshahr. The task of destroying the pest proved heavy, but was everywhere carried out with a very large measure of success.' Hoppers assumed the adult stage by May and began to fly, the general direction of flight being west to east or north-west to south-east. Though few swarms were to be seen east of Cawnpore in mid-May, flights reached as far east as Gorakhpur and Ghazipur by the end of the month.

In this connection it must be noted that swarms of pink locusts bred in the Punjab and Baluchistan areas also entered the United Provinces from the west and presumably became amalgamated with those produced locally.

Breeding in Sind. Some breeding is reported to have occurred in the Manganwari area of Rohri Taluk in Sukkur district near the boards of the Khairpur State and it may be presumed that breeding had also extended into the State territory. Numerous locust flights are said to have occurred in spring in the Sind area.

Western Flights were first noted in Sind on the 24th April in Karachi district and on the 26th April in Nawabshah, Larkana and Upper Sind Frontier districts. During May, numerous flights were reported all over the Province, generally passing west to east.

North—West Frontier Province. Data are scanty in regard to the earlier part of the year, but swarms were apparently present in considerable numbers at the end of April and were presumably derived from the Punjab. In May, breeding was reported from the Risalpur area of the Peshawar district.

Movements in the Rajputana Area. There was no breeding anywhere in Rajputana during the spring months, except for small numbers of hoppers reported from the Karanpur tahsil of Bikaner State.

In March several swarms were observed in Alwar, near Marwar—Kishengarh borders and in Jaipur, and in April a few swarms passed over Bhurtpore State into Muttra district. In May, numerous flights were reported in Rajputana in Bhurtpore, Kotah, Dholpur, Jaisalmer, Bundi, Jaipur, Tonk and Kishengarh States being evidently composed of migrants of Baluchistan and Persian origin coming from the west.

III. *Summer 1930:* (June-July 1930)

Summer Flights. As already mentioned, swarms from the west were migrating into Sind, Rajputana and the Punjab during May, especially in the later part of the month, and were mixing with the swarms bred in the Punjab and the United Provinces. The movements of these swarms were, on the whole, west to east or north-west to south-east, and generally coincided with the direction of the hot, dry westerly winds that developed in the Indo-Gangetic Plains during April-May-June. Many swarms passed into the United Provinces and reached the extreme east by the end of May. Others passed into the States of *Central India.*—Narwar and Bhind in Gwalior State in May; and into Jaora, Basoda, Bhopal etc., in June. Certain swarms entered the *Central Provinces* at the end of May in the Hatta and Raneh Tehsils of Damoh and others were found during June in many other parts of that district. In July some were reported from Saugor district as well as Damoh and were said to damage millets, pulses and jowar. Locusts were reported from Palamau district in Bihar and Orissa on the 11th June, entering the area from the north-west, presumably from the United Provinces areas, as also from Patna and Gaya districts at the end of June. In July flights coming from the east were reported at Ranchi.

On the 11th June 1930, a locust swarm 2 miles square was observed at Udayagiri in Ganjam district (*Orissa Province*) at 11 A.M. and was said to have come from a western direction and to have damaged vegetables and young crops. Apparently this swarm had come from the direction of the Central Provinces, which would indicate that at this period some flights had passed over the eastern parts of this province without having been observed or at least without having been reported.

Towards the south-east, the flights from the west reached Palanpur, Radhanpur and Wao States in the third week of June presumably *via* Rajputana. Some swarms were also reported from Khavda ilaqa in Cutch State during June.

A study of the movements of swarms in Punjab and United Provinces during the period—May to July—has proved very interesting. The advent of the immigrant swarms from the west began in May and by the end of the month, they had spread over the Punjab and passed over

the United Provinces until they had reached the extreme eastern limits *viz.*, Gorakhpur and Ghazipur, and presumably several swarms had thence entered Bihar and Chota Nagpur. In June, flights were reported from the Orchha and Rewa States of Central India and from the Palamau, Patna and Gaya districts of Bihar and one swarm was found in Ganjam district on the Orissa Coast. By the middle of June, however, many of the swarms in the eastern parts of the United Provinces and a few in Bihar were seen to be moving westwards. This tendency continued during July, till by the 19th the whole of Bihar and eastern United Provinces was clear of locust swarms. There were, on the other hand found concentrating in the western districts of the United Provinces and in the Punjab and Rajputana areas.

Examining the meteorological conditions of this period: May-June-July 1930, it is seen that, while during the first fortnight of May, easterly winds prevailed on the Gangetic Plain under the influence of certain depressions at the head of the Bay of Bengal, westerly winds were observable from the 16th to very near the end of May, which apparently helped to carry the swarms over the United Provinces into Bihar (*vide* Pl. 49).

In June, there was a development of conditions preliminary to the advance of the Bay monsoon during the first fortnight, with easterly winds in the northern parts of Bihar and the United Provinces and strong westerlies in the southern parts, such as parts of Central India, the Central Provinces, Chota Nagpur and the southern districts of United Provinces. During the second half of June and during July, with the progress of the Bay current, strong easterly winds prevailed in Bihar and United Provinces, so that most of the locust flights took a westerward direction, the result being that the eastern parts of the Gangetic Plain were clear of locusts by July (*vide* Pl. 50). Swarms became concentrated in the districts of eastern Punjab and western United Provinces, where in consequence of good rainfall in July, extensive oviposition occurred in July-August. With a continuation of the monsoon conditions, during July-August, swarms were gradually carried further west during August into the central and north-western parts of the Punjab, where egg-laying continued till the middle of September.

Summer Breeding. As there was fairly good rainfall in the eastern parts of Baluchistan, and in Sind, Rajputana, the Punjab and the United Provinces, extensive breeding occurred in these areas.

Baluchistan.. During June, late spring breeding continued in the districts of Quetta-Pishin, Zhob, Sarawan and Jhalawan and also in Bhag Niabat in Kachhi.

Flights of pink swarms from the west continued in July and August in many parts of Baluchistan. In Lasbela, for instance, a large swarm of red locusts, 6 miles by 6 miles—appeared on 23rd August from the west in Velpat and damaged crops.

With good rainfall in July, breeding occurred in the Musakhel and Barkhan talukas of Loralai district: and in Habnadi, Uthal, Liari and Levies Tracts areas and also in the Ormara area of Lasbela state, in the Pasni area of Mekran (where there was an abnormal fall of 5·15 in. in July); and in Karkh in Jhalawan. Breeding continued till September.

Sind. Breeding occurred in July-August in Thar-Parkar district (Mithi, Nagar Parkar, Chachro and Diplo); in Karachi district (Gadap, Jungshahi, Kohistan and Tatta) and in parts of Hyderabad district.

The Punjab. Rains started early in the south-eastern districts in June, as in the case of the adjoining parts of the United Provinces. These were followed by heavier falls in July and August, but there was a long break in the monsoon from the 18th August up to 6th September.

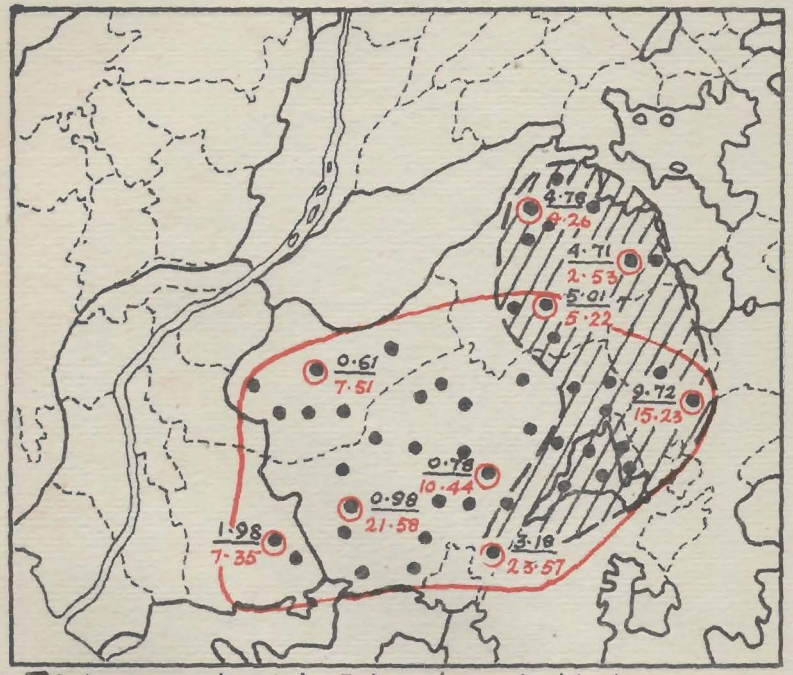
Early in July oviposition commenced in the eastern districts of the Punjab: Hissar, Gurgaon, Rohtak, Ferozepur, Karnal, Ambala and Ludhiana as well as in Delhi Province, at about the same time as in the adjoining western districts of the United Provinces. Egg-laying extended later on to the central and northern districts with the gradual advance of the monsoon. On the whole, twenty-four districts were affected during the summer season, *i.e.*, practically the whole of the Punjab except the hill districts of Simla and Kangra and the western districts of Multan, Jhang and Shahpur. Hatching began about the 20th July and oviposition as well as emergence of hoppers continued in August. Control measures against hoppers were in progress throughout September and some hoppers were still found even in the last week of October in Gurgaon.

United Provinces. During the latter part of June, locust swarms were present throughout the province including the easternmost districts of Ballia and Mirzapur, but in the course of July, they appeared to be moving gradually westwards, so that by the 20th very few flights were to be seen east of Lucknow and Cawnpore. Oviposition occurred mostly in the western districts during July and hatching commenced in the last week of the month. Seventeen districts (Saharanpur, Muzaffarnagar, Meerut, Agra, Etah, Mainpuri, Etawah, Cawnpore, Jalaun, Bijnor, Bulandshahr, Aligarh, Muttra, Moradabad, Budaun, Shahjahanpur and Lucknow) were affected in 1930, and it is rather remarkable that both in 1929 and 1930 almost the same area had been affected (Jumna-Ganges Doab), the only difference being that, while in 1929 the easternmost limits of oviposition were Bara-Banki and Allahabad, in 1930 the furthermost point was Lucknow. It is note-worthy that the districts infested have, on the whole, an annual rainfall lower than either the submontane districts adjoining the Himalayan foothills, or the eastern districts. At the same time, it is obvious that both in 1929 and 1930, swarms that had occupied the eastern parts of the United Provinces had been literally swept back by the easterly winds of the Bay Monsoon into the western districts and probably carried further west into Punjab and Rajputana. It appears likely that the peculiar distribution of the ovipositing swarms was due more to the action of the prevailing easterly winds than to the influence of the relative amount of rainfall.

Egg-laying and emergence were observed throughout August and continued till the 2nd week of September. According to the Administration Report of the United Provinces Agricultural Department for 1930-31, it would appear that "Locust invaded over 467 villages in the United Provinces during 1930 and the attack, being less severe than in the previous year, was successfully dealt with by the district staff."

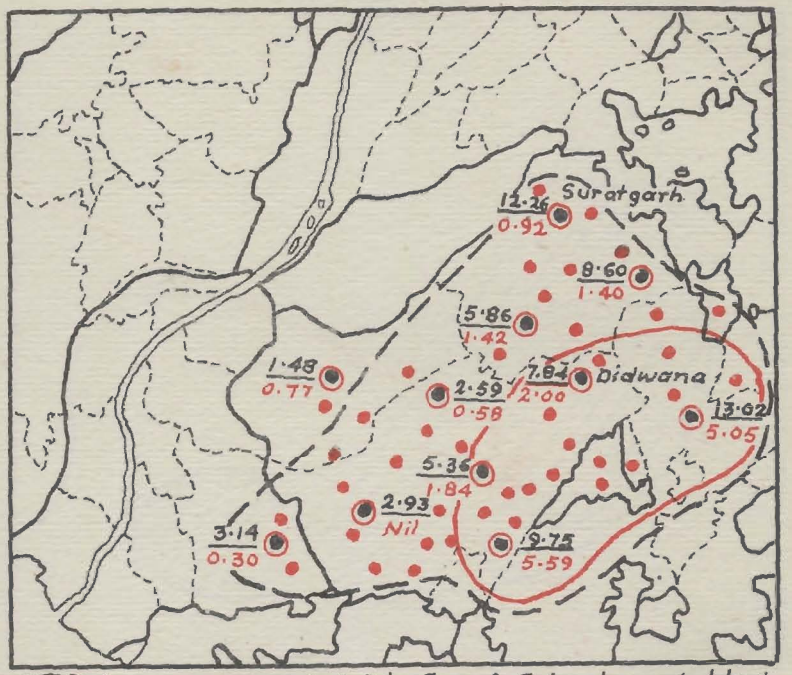
N. W. Frontier Province. Hoppers of the spring brood were still to be seen at the end of June in Peshawar. Flying swarms were reported at the end of June and during July in Peshawar, Kohat and Bannu districts and in Kurram Agency, being presumably representatives of the summer immigrants from the western areas, but disappeared from the Province by the middle of July. By the end of July, however, yellow swarms from the Punjab invaded the Bannu, Kohat and Dera Ismail Khan districts and the Kurram area, and in August some swarms were

FIG. 1 SIND-RAJPUTANA AREA: BREEDING IN 1931



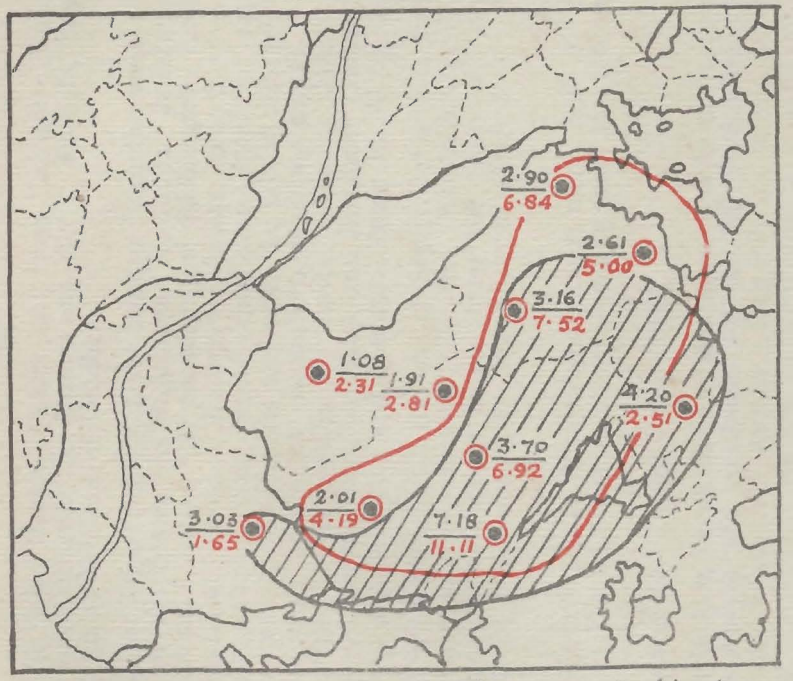
Area of rainfall in July shown in black.
Area of rainfall in August shown in red.
4·71 / 2·53 Rainfall in inches with station.
• Locality of breeding.

FIG. 2 AREAS OF SUMMER BREEDING, 1930
SIND-RAJPUTANA AREA



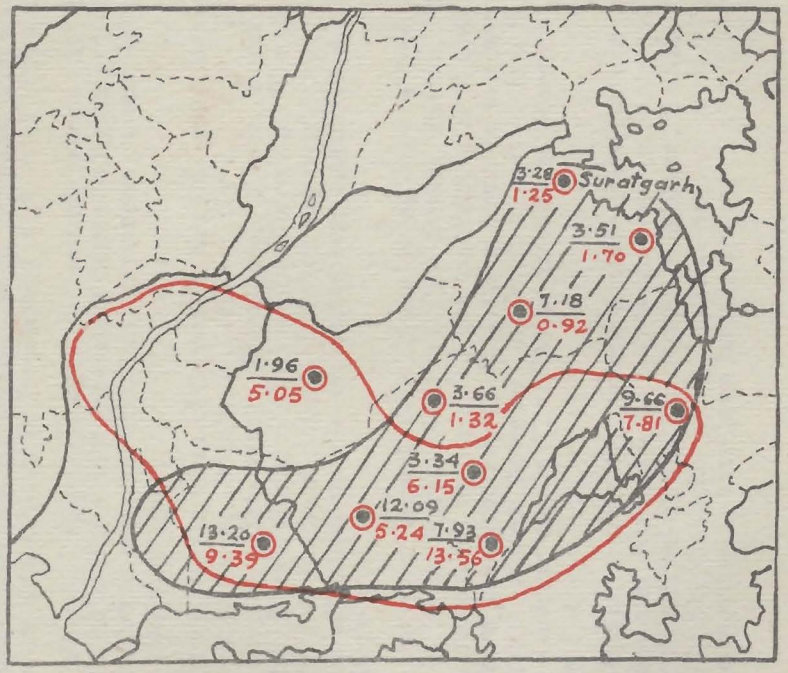
Area of good rainfall in June & July shown in black.
Area of good rainfall in August shown in red.
2·53 / 1·42 Rainfall in inches with station.
• Locality of breeding

FIG. 3 AREAS OF SUMMER BREEDING, 1928
SIND-RAJPUTANA AREA



Area of good rainfall in July shown in black.
Area of good rainfall in August shown in red.
1·09 / 2·81 Rainfall in inches with station.

FIG. 4 AREAS OF SUMMER BREEDING, 1929
SIND-RAJPUTANA AREA



Area of good rainfall in July shown in black.
Area of good rainfall in August shown in red.
3·66 / 5·05 Rainfall in inches with station.

reported also from Hazara district and from Razmak. Breeding would appear to have occurred in Bannu and Kohat districts, hoppers being observable up to the end of October.

Breeding in Rajputana. Migrant swarms from the west were passing over most of the States in Rajputana in June: Jaisalmer, Jodhpur, Bikaner, Sirohi, Jaipur, Ajmer-Merwara, Kishengarh, Bundi, Tonk, Karauli, Jhalawar, Dholpur, Bhurtpore, Alwar; generally west to east. During July, swarms were found migrating from the east from the United Provinces or the Punjab, and with the fall of rain, egg-laying was observed in many parts of Rajputana, in the course of July and August:—Bikaner, Kishengarh, Bhurtpore, Alwar, Jaipur, Dholpur, Tonk, Jodhpur (most of the Parganas), and Jaisalmer (Jaisalmer, Mohangarh, Nachna and Vinjorai) and Merwara (*vide* Pl. 44 fig. 2).

Hoppers were present till the end of September and as far as possible control measures were organised by the Administrative Officers of various states against hopper bands under the technical advice of the Locust Bureau Entomologist of the Imperial Council of Agricultural Research.

In the Western Indian States Agency, eggs were laid in the middle of August in Tharad State by swarms coming from the Marwar areas.

IV. *Autumn 1930*: (Sept.—Nov. 1930)

As a fairly long break in the rains developed in northern India from about 18th August and continued till the 7th September, rainfall was very much in deficit in August. Oviposition ceased as a result of drought by the end of August in many places and by the middle of September in almost all parts. Consequently there was no late mass-breeding as in 1929, although hoppers resulting from scattered oviposition were noticeable late in October as in Gurgaon and Gurdaspur in Punjab, and in Kohat (even in November) in N. W. F. Province.

Autumn Flights. Hoppers began to assume wings by the end of August and adults of the new generation began to fly early in September. Large flights were seen all over the provinces where breeding had occurred during September.

In *Rajputana*, flights were observed in August-September in all parts of western Rajputana: Jaisalmer, Jodhpur, Sirohi and Bikaner, as well as in Jaipur, Kishengarh, Bhurtpore, Alwar, Bundi, Banswara, Mewar, Tonk, Kotah, Jhalawar and Ajmer-Merwara. The directions of flights varied, but the most general direction appeared to be west to east or south-east after the middle of September, especially in the eastern States of Rajputana.

In *Sind*, breeding ceased early, there being only a few hoppers in September in Nagar Parkar tehsil of Thar-Parkar district. In September there were general flights in all the districts of Sind and the Khairpur State from the direction of Rajputana towards the west or south west. Migration ceased, however, in October, only a few flights being recorded in Larkana and in Thar-Parkar (Mithi) in November, and none in December.

In *Baluchistan*, hoppers that emerged in the Pasni area in July-August became adults and disappeared towards the east in September. Several swarms were reported during the month in Mekran, Loralai, Sibi (Dera Bugti), Kachhi and Lasbela flying mostly east to west. In Lasbela, hoppers were reported to have been largely destroyed by the 'Wahya' birds

(Rosy Pastor), and those that were left changed into adults by the middle of September. By the end of the month, Lasbela was clear of locusts.

During October, there are only two records of flights in Barkhan tahsil of Loralai district on the 7th, after which there were apparently no further reports.

In the Punjab, breeding continued till the end of September, by which time all the hoppers that had escaped destruction changed into adults in batches. During August-September, flying swarms appeared to be moving partly east into the United Provinces and partly south-east into Central India. In October, though a few hoppers were still reported from Gurgaon and Gurdaspur, the Punjab appeared to be clear of locusts except for a few swarms seen in the Dera Ghazi Khan, Ferozepur and Gurgaon districts. In November, there was only a single report from Simla and in December, a few swarms were observed in Patiala State, Montgomery, Hoshiarpur, Lyallpur and Multan.

In the *United Provinces*, swarms were observed coming into the province from the direction of the Punjab from the 3rd week of August. This was presumably due to the prevalence of westerly winds during the long break in the monsoon which lasted from the 18th August to the 6th September. By the end of the 1st week of September, swarms had reached Gorakhpur and Ballia districts—the eastern limits of the province. There is little doubt that some of these swarms had penetrated therefrom into Bihar and Bengal at this time, as a large swarm is recorded as having entered Goalpara district (Assam) from Rangpur district (Bengal) during the last week of September, and thence moved into the Garo Hills.

From the 7th September up to the 16th September, the Bay monsoon was again active and during this period strong easterly winds prevailed in the United Provinces and Bihar, and as a result of this circumstance, most of the swarms in Bihar and Eastern United Provinces would appear to have been gradually carried westwards or south-westwards into the States of Central India (Rewa, Nagod, Orchha, Gwalior etc.) and into Central Provinces, so that by the end of September, there were no locusts left in the United Provinces except in the extreme west in Meerut and other districts.

There are no further reports of locust swarms in the United Provinces till the last week of November, when flights of young locusts are said to have occurred in Mirzapur, in which district there were further reports of swarm activity during the 3rd and 4th weeks of December.

Migration into Central India and Central Provinces. By the middle of September, swarms derived partly from Rajputana and partly from the United Provinces were found moving south and south-east into Central India and thence in the direction of the Central Provinces, reports being received from various States in Central India such as Rewa, Orchha, Bhopal, Sitamau, Jaora, Jhabua, Indore, and Barwani States.

During the 3rd week of September, swarms were reported entering the Central Provinces. The earliest movements were reported from Saugor district where locusts coming from the north-east, presumably from the United Provinces, were observed. The next report was from Nimar district (Khandwa) on the 20th whence flights passed eastwards into Betul and thence into Hoshangabad district under the influence of the south-west winds. From the 23rd onwards, numerous flights were reported up

to the end of the month in Berar and West C.P. (Akolo, Amraoti and Yeotmal, Jubbulpore, Narsingpur, Seoni, Betul, Chhindwara, Nagpur and Bhandara districts). From the 20th to the 29th September, strong northerly currents of wind were generally prevalent in the region of east Rajputana, Central India, Central Provinces and Hyderabad State, under the influence of a depression at the head of the Bay of Bengal, inducing a southward trend in the flights of locusts (as shown in Text. Fig. 24). Under these circumstances, swarms spread into most of the districts of Berar and west Central Provinces and presumably passed therefrom into parts of Hyderabad (Deccan). However, the only report received from the Nizam's territory was from Warangal district, where pink swarms were observed on the 28th September and 1st October at Mulug. Since it was reported later on that swarms passed into Yeola from Aurangabad district early in October, it is quite likely that some swarms had also invaded other districts in the northern part of Hyderabad State, at the end of September. Some of the swarms reaching Jubbulpore, Mandla and Seoni would appear to have, however, crossed over towards the east and reached Bihar and Orissa (Ranchi, Sambalpur) and Bengal (Rajshahi) in the 1st week of October.

In October, with the advent of the retreating monsoon, north-easterly winds developed in north Deccan, and as a result thereof, swarms were found entering Khandesh and Nasik from Berar and Aurangabad about the 7th October. From Nasik they reached Surat, Thana and Kolaba districts and invaded several villages in the valleys of the Sahyadri Hills, from which they passed, later on, into the adjoining villages of the Poona district. Reports of the activities of swarms in these areas were being received till the third week of November.

Western India States. In September locust swarms hailing from the Rajputana area were reported from Tharad, Palanpur and Jasdan. In October, flights presumably of Rajputana origin visited various parts of Kathiawar and Gujarat, Wadhwan, Junagarh, Bhavnagar and Porbandar, Tharad, Wao and Radhanpur; and Kaira and Ahmedabad. In November and December, locusts were being reported from more or less the same areas and also from the Cutch State.

Migration to the East: Central Provinces, Bihar, Bengal, Assam. In the Central Provinces as well as in eastern Central India States and Bihar, the seasonal westerly winds set in from about the middle of October and generally prevailed during November-December. Most of the swarms, which had been concentrated in west Central Provinces and possibly in north Hyderabad during September and early October, began to shift eastwards across some of the eastern states, *e.g.*, Chhuikadan, Kanker, Khairagarh, Drug and Udaipur and had apparently passed into Bihar and Orissa (Ranchi, Sambalpur, Singhbhum and Manbhum) and Bengal (Nadia, Pabna, Dinajpur and Rajshahi districts) by the 3rd week of October. Some swarms would appear to have passed from the Rangpur district into parts of the Goalpara district of Assam (Dhubri and Jogighopa) and moved on into the Garo Hills by the end of October.

In November, more swarms passed eastwards and northwards from the Central Provinces through Santhal Parganas in Bihar into north Bengal (Jalpaiguri and Darjiling) and ultimately into the districts of Goalpara, Kamrup (Barpeta, Rangia and Jaintipur and Charduar in Balipara Frontier Tract) and Sibsagar (Dergaon etc.). Further movements were reported in December, flights passing from Central Provinces *via* Mirzapur district in south United Provinces, and Ranchi, Palamau and Monghyr in Bihar, into Bengal and Assam. In Assam which

consists in great part of the Brahmaputra valley running east to west and is bounded on the north and the south by high hill ranges, the winds are almost invariably strong easterlies throughout the year and generally very few locust swarms would fly against these wind currents, so that Assam (especially the interior) is in general free from locust invasions. In November and December 1930, however, locust swarms reached as far east as Dibrugarh in Lakhimpur district. Towards the end of November large swarms appeared in Kamrup, Sibsagar and Darrang districts and passed on further east into Balipara Frontier Tract, where early in December they were noticed flying over trees and bamboo bushes for 2 or 3 days. They are said to have "passed often hundreds of feet above the tallest trees and the size and expanse of the swarm was apparently often large enough to obscure the view of the open sky for half an hour at a time. *Sali* paddy and sugarcane were among the crops damaged". The Manager of a Tea Estate at Mazbat, Tezpur division reported on the 5th December 1930: "Within the last two weeks there has been a great influx of locusts—the ground being covered with them. Shade trees and *Tephrosia candida* were denuded of young growth and vegetable gardens attacked. Tea was not touched. Locusts had not been seen in such large numbers ever before." [Andrewes—1916].

As regards the direction of winds in Assam, it is seen from a study of the Daily Weather data that the usual direction at 8 A.M. is from east to west. Winds were westerly in autumn, 1930, in Assam stations only on rare occasions:—19th, 23rd, 30th and 31st October and 7th December. There does not appear to be much correlation between the direction of wind and swarm movements in Assam from the data available. It is generally during the afternoons that flights take place and it is possible that the movements to the east might have occurred under the influence of favourable winds. Possibly, the winds in question were weak, in which case locust swarms may be supposed to have steered an independent course.

Summary of Events in 1930: (Plate 48)

(1) The winter-spring rainfall was satisfactory in Oman, Baluchistan and Punjab.

(2) Over-wintering swarms were present in Sind, the Punjab and Baluchistan and the hill districts of United Provinces.

(3) With the fall of winter rain, egg laying began in February in Mekran and in March in Chagai, Kharan and Jhalawan. In April and May, oviposition occurred in the upland areas of Baluchistan, and in Kachhi.

In the Punjab, oviposition began in February. Breeding occurred in twenty-five districts and the new generation began to appear early in May. In the United Provinces, eggs were laid in 12 districts inclusive of the hilly areas of Almora, Garhwal and Dehra Dun. There was light breeding in Sukkur district in Sind and in Peshawar district in N.W.F. Province.

(4) Western summer migration commenced at the close of April in Sind and Baluchistan and in May in the Punjab and Rajputana and United Provinces. The swarms reached as far as Gaya, and Ranchi in Bihar and the Ganjam Coast in Orissa.

(5) With the setting in of the Bay monsoon current, easterly winds prevailed in United Provinces and had the effect of sweeping the swarms

back from the eastern districts of the United Provinces and concentrating them in western United Provinces, Rajputana and the Punjab.

Breeding occurred in 17 districts of the U.P. and in 24 districts of the Punjab and in Delhi Province. Fairly heavy breeding also occurred in many parts of Rajputana, including Jaipur, Bhurtpore, Alwar, Kishengarh, Tonk, Dholpur and Merwara, in addition to Jodhpur, Bikaner and Jaisalmer.

Breeding occurred also in Thar-Parkar, Karachi and Hyderabad districts in Sind, in Lasbela State, at Pasni in Mekran, and in Loralai, Kachhi and Jhalawan.

(6) There was a prolonged break in the monsoon from the 15th August to 6th September on account of which there was no late breeding in 1930. Flights towards the west ceased by the end of September. Most of the swarms produced in Rajputana, United Provinces and the Punjab, moved south in September-October into Central India and Central Provinces and thence into Bombay and Hyderabad (Warangal) and eastwards in October-November-December into Bihar, Bengal and Assam.

YEAR 1931

A. Weather Notes 1931

I. *Winter-Spring Rainfall 1930-1931*: (*Monthly totals in inches*)

1930-31	Nov.	Dec.	Jan.	Feb.	March	April	May
Iran :							
Bushire	0·12	1·57	3·35	3·45	..	0·12	..
Jask	..	1·09	0·77	4·13	1·46	..	..
Charbar	..	..	2·55	1·03	..	..	..
Seistan	0·08	0·11	0·37	1·34	0·42	0·30	0·04
Meshed	0·05	0·68	1·85	1·88	2·59	2·84	2·59
East Arabia :							
Muscat	..	..	0·65	3·39	0·26	0·22	..
Bahrein	..	0·83	1·24	2·73	..	0·53	..
Baluchistan :							
Pasni	..	..	2·62	1·90	1·19	..	..
Panjgur	..	..	0·28	1·39	1·21	0·02	..
Turbat	..	..	0·48	1·12	0·82	..	0·75
Sonmiani	..	..	0·60	2·00	0·10	..	..
Quetta	0·15	0·21	2·22	5·03	1·89	1·03	0·48
Chaman	0·02	0·04	1·47	3·22	0·85	0·15	0·52
Nushki	..	0·05	1·04	5·10	0·33	0·52	0·08
Kalat	0·03	0·03	1·13	4·90	0·47	0·39	0·07
Rindli	..	..	..	1·60	..	0·01	0·44
Sind :							
Karachi	..	..	0·15	0·14	0·21	..	..
Jacobabad	..	..	0·01	0·39	0·05	..	0·64

1929-30	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Punjab							
Rawalpindi	0·10	0·01	3·29	2·43	2.61	1·43	2·21
Gujrat	..	..	3·36	1·03	1·07	0·12	1·97
Lahore	..	..	1·72	0·91	0·99	0·26	0·83
Ambala	..	1·20	0·26	2·79	0·85	0·04	0·63
Hissar	..	0·10	..	0·06	0·40	0·52	..
D. G. Khan	..	..	..	0·29	0·27	0·09	0·78
United Provinces							
Roorki	..	1·69	0·01	2·70	0·65	..	0·62
Agra	..	..	..	0·26	..	0·02	0·00

There was not much rainfall in winter till February 1931, when widespread rain or snowfall occurred in various parts of Baluchistan. Precipitation was above normal in almost all other parts of north-west India. In March, rainfall was normal in the Punjab but defective in Baluchistan, but in April it was in defect everywhere.

II. *Monsoon Rainfall Data 1931: (Monthly totals in inches)*

1931	May	June	July	Aug.	Sept.
Baluchistan					
Sonmiani	..	..	..	0·03	..
Bela	0·77	..	..	0·72	..
Rindli	0·42	..	..	..	..
Loralai	0·45	0·32	0·75	0·72	..
Sind					
Karachi	..	0·08	0·15	0·03	..
Jacobabad	0·64	0·01	0·01	..	..
Mithi	0·35	..	0·02	5·23	0·52
Chachro	0·75	..	1·98	7·35	2·87
Rajputana					
Barmer	0·76	0·34	0·98	21·58	0·62
Jodhpur	0·78	0·29	0·78	13·02	0·05
Phalodi	1·55	0·42	1·74	5·40	0·11
Jaisalmer	1·49	0·62	0·60	7·51	0·31
Devikot	..	0·75	0·50	6·30	..
Bap	0·12	0·98	1·56	7·44	..
Bikaner	0·43	0·42	5·01	5·22	..
Nohar	0·20	0·05	4·08	5·62	1·21
Jaipur	0·18	0·34	9·72	15·23	0·51
Ajmer	1·01	0·15	5·96	10·23	0·14

1	2	3	4	5	6
Punjab:					
Rawalpindi	2·25	0·42	9·01	7·87	3·31
Lahore	0·85	0·05	9·77	9·60	2·24
Gujrat	1·97	..	9·43	7·79	0·37
Ambala	1·59	0·16	6·21	12·32	1·46
Hissar	0·66	0·14	6·14	3·49	4·00
D. G. Khan	0·78	0·08	1·85	..	..
United Provinces:					
Roorki	0·63	0·46	10·55	7·43	12·03
Agra	0·06	0·77	4·57	7·28	9·77

The Bay monsoon extended into Rajputana and the Punjab by the 13th June. Though there were numerous dust and thunderstorms in north-west India, rainfall was in defect generally. In July, there was normal monsoon in N. W. India except in Sind, Baluchistan and N. W. Frontier Province, where rainfall was in large defect. In August, several depressions appeared in northern India, in the course of which there was excessive rainfall in Rajputana and in east and north Punjab, but in the United Provinces and in Sind, Baluchistan and south-west Punjab, it was in defect. In September, the monsoon was normal in Punjab, and N. W. Frontier Province, but weak in Rajputana, and withdrew from N. W. India from the 10th September.

B. *Locust Data* 1931 (*Vide Pl.* 51)

I. *Winter 1930-31* (Dec. 1930 to Feb. 1931)

Over-wintering swarms were found in January in parts of Bihar, Bengal and Assam and Western India States.

A few pink swarms apparently coming from the direction of Central Provinces were reported in the United Provinces on 5th January from Dudhi tahsil of Mirzapur district and a few, in Bihar from Palamau and Shahabad districts also on the same date, and from several places is Gaya district on the 9th January 1931. On the 20th January, a swarm was observed in Bengal at Nahatta, 10 miles north of Rajashahi, coming from south-west and flying north-east after causing slight damage to peas, mustard and *Rai*. On the afternoon of the 27th January, locusts appeared in Dhubri from across the Brahmaputra River coming possibly from the Garo Hills.

These are indications that in January swarms were following the same course of flight as in November and December 1930. As there were no further reports of locusts in Bengal and Assam, it may be presumed that the swarms fell a prey to birds and other natural enemies and became disintegrated.

Except for some swarms reported from the Cutch and Radhanpur States causing slight damage to wheat in early January, there was no information from other parts of India.

Situation in Winter and Spring in Persia and East Arabia

According to Predtechensky [1935], no locusts were seen during the winter of 1930-31, along the coast of the Persian Gulf (Hormuz, Lingeh,

Bunder Abbas or Minab). According to Uvarov [1933], "the situation in Persia during the winter 1930-31 was very quiet until February, when some swarms are stated to have appeared in the southern part of Persian Baluchistan." "The first flights of the yellow locust" according to Predtechensky [1935] "appeared on 31st March on the island of Qishm, where they arrived from the direction of the Oman Peninsula of Arabia. On the 1st April some swarms flew across the straits separating the island from the south Persian Coast, into the latter territory in the region of Bunder Abbas, and in the evening they appeared in the Minab region. In the first decade of April, oviposition occurred in the latter region. Mass hatching of hoppers took place in the early days of May and hoppers began to get wings at the end of the month, and the winged specimens flew to the hills in the north."

There is little information in regard to the situation in East Arabia, except that no swarms had been seen in December 1930 in Oman. In March 1931, flights would appear to have reached Koweit from Najd and to have bred in April and May.

Since the rainfall in January and February was fairly satisfactory at Muscat and Bahrein, it may be presumed that breeding had taken place in Oman and Hasa also during the spring months.

II. *Spring* 1931 (March to May 1931)

The earliest report of a swarm in North-West India was on the 14th March from the Punjab at Kabirwala (Multan district) which was evidently concerned with a concentration of locusts overwintering in the neighbouring areas.

In Baluchistan, a report was received on the 18th March, from Nushki (Chagai district) of a hatching of hoppers, which proved to be a case of false alarm as the specimens received were those of grasshoppers.

The first report of actual swarms was in the first week of April in the Panjgur district of Mekran and the Mashkai Niabat of Jhalawan. In the second week of April, flights were sighted on the 14th at Grawag in the south of Kharan, and on the 13th at Mirjawa on the Persian borders of Chagai. On the 7th and 18th April, swarms are reported to have appeared in the Dalbandin Tahsil from the direction Mashkel in Kharan and to have flown away east towards Nushki. On the 19th some yellow locusts were noticed further east at Panjpai. Further flights from the direction of Kharan appeared in parts of Dalbandin and Nushki Tahsils in April, where oviposition also occurred. There were several flights in Kharan also followed by egg-laying. On the 28th April, swarms penetrated into Panjpai in Shorarud, into Kirdagap and Mastung in Sarawan, and into Mashkai, Gidar and Khuzdar in Jhalawan. Some swarms are also reported to have entered Lasbela area on the 20th April from the south at Pohr and from the west on the 21st at Bela. There is a report in the Lasbela records in regard to the appearance of hoppers in March in parts of Lasbela and enquiries made in 1932 showed that at Khandewari in the south-western part of Lasbela, light breeding had taken place in February-March after rainfall, as a result of a small incursion of yellow locusts from the western hills (possibly from Mekran side).

In this connection, it may be stated that a flight of locusts passed over Jacobabad in *Sind* on the 17th April from a north-west direction and a smaller concentration of yellow locusts was seen roundabout that place on the 21st. It was also reported that early in April swarms came from Chaman side into Kandahar area, some of which seem to have laid eggs in Kalat-i-Ghilzai, and others to have departed towards Herat.

These data would show that flights of Oman origin had passed through Persian-Baluchistan into Mekran and Kharan, thence into Chagai, Shorawak and Upper Baluchistan to the north-east, and Jhalawan, Lasbela and Sind to the south-east.

By the beginning of May, locusts had reached the Quetta-Pishin district and were laying eggs mostly in the beds of streams and water-courses as in Lora Hyderzai near Kuchlak. The swarms would appear to have come from the west from Panjpai side *via* Dinar Karez into the Surkhab river area. By the end of May, eggs had been laid in various places in Pishin tahsil such as Segi, Sarwisht, Gulistan, Regi, Khanai and Torashah. In Zhob district, breeding occurred in Kibzai circle of Fort Sandeman Tahsil in May. Breeding occurred in Sarawan (Kirdigap, Mastung and Ghulaman, Dasht Thana and Kolepur), in Jhalawan (Surab) and in Mekran (Gwargo in Panjgur Ilaqa). Breeding also continued in Chagai district at Nushki, Ahmedwal, Dalbandin and Panjpai.

In the *Punjab*, there were no reports of locusts after March, till the 29th May when a swarm was reported at Multan coming from Muzaffargarh. At about the same time in the N. W. Frontier Province, the first swarm was observed on the 27th May, passing over the Kurram Agency south-east to north-west. It is presumed that both of these had been derived from the infestation in Loralai and Zhob in Baluchistan.

Rajputana. On the 7th March, a swarm passed over Jhalawar territory (Awar and Dag tahsils) coming from Tonk and Gwalior States and flying in various directions. In May, two swarms were recorded in Jodhpur State: one during the first week at Jodhpur and the other on the 23rd in Siwana Pargana. Presumably all these represent the over-wintered generation produced in the autumn of 1930.

Breeding in Extra-Indian Areas

In Afghanistan, breeding was reported to have occurred in the Kalat-i-Ghilzai areas and possibly around Kandahar.

In Iran, spring breeding took place in the Bunder Abbas area and in parts of Baluchistan, Seistan and south Khorasan, in April and May. In Arabia, the appearance of "Dibba" (Hoppers) was reported in April-May in Koweit, an indication that breeding should have been possible also in other parts of east Arabia, as in the Hasa and Sharjah areas.

III. *Summer 1931* (June-August 1931)

Spring breeding continued in Quetta-Pishin, Chagai, Sarawan and Jhalawan and most of the hoppers became winged by the end of June.

Summer Flights. Hoppers in the Chagai area began to change into adults by the middle of May, and swarms of the new generation began to migrate by the end of May. Pink swarms were first noticed in Sarawan, Jhalawan, Mekran and Lasbela by the first week of June.

The first swarm in Sind was noted at Sehwan in Larkana (now in Dadu) district on the 12th June. By the middle of June, further flights of pink locusts were reported in almost all the upland areas of Baluchistan: in Sarawan, Quetta-Pishin, Sibi, Loralai and Zhob districts, presumably from breeding areas in Afghanistan and Persia. On the 18th, the 20th and the 29th June, the passage of three large pink swarms through the Quetta valley, was witnessed by the writer. The first one was seen at 10 A.M. at Kuchlak about 20 miles to the north-west of Quetta by Mr. Baweja and other locust control staff working there. The major part of the same swarm entered the Quetta valley at noon and was found passing, on the afternoon of the 18th along the narrow open plain stretching between the Chiltan Range on the west and the Murdar Range on the east. The direction was north-west to south-east, and the main body of the swarms was flying very high and locusts were seen as tiny specks against the silvery back-ground of large cumulus clouds. It was found by one of the observers of the Quetta Meteorological Observatory, who was following the ascent of an observation balloon with a telescope that locusts could be found up to a height of nearly 2,000 ft. above the ground. *On the 20th*, the swarms were noticed at 12 noon and were passing much lower, and a good many locusts alighted on the ground and attacked cabbages and other garden plants. *On the 29th*, the third flight, which was by far the biggest of the three, was first seen at 3-30 P.M. and continued to pass along the valley until sunset (8 P.M.). No observations were made as to whether the flight continued after darkness set in, but it appears likely that it did, for one or two hours at least, as the evening was fairly warm. It was found that the swarm had reached the neighbourhood of Spezand about 15 miles off by night-fall. About 10 per cent. of the pink locusts collected from swarms passing through Quetta were found to be parasitised by Sarcophagid maggots, the adults reared from which were identified by the Imperial Institute of Entomology, London, as *Agria latifrons* Fln.

On the 5th July, stragglers were found on bushes in open stone-strewed plains near Spezand. On the 7th, a small flight was observed to be carried by winds eastwards between Dasht Thana and Spezand, and on the same date there is a report that a red swarm had entered Kahnak from Shorarud and had passed towards Quetta (possibly the same flight).

Numerous swarms were reported in most parts of Baluchistan especially in Zhob and Loralai during July, most of which were directed towards the east or south-east, except during periods when easterly winds prevailed on account of the activity of depressions.

The flights from the west reached the Punjab first on 20th June at Rajanpur in the D. G. Khan district flying south-west to north-east, and on the 22nd June at Isakhel in Mianwali district coming presumably from Bannu district in N. W. Frontier Province. It may be mentioned in this connection, that some swarms were reported to be active in the Parachinar-Kurram area in the Kurram Agency between the 18th and the 20th June, where they had arrived from a western direction—presumably from the Kalat-i-Ghilzai and Ghazni areas of Afghanistan. Eggs would appear to have been laid by these locusts in Kurram Agency in the third week of June, as hopper emergence was reported to have occurred on or about the 9th July.

Swarms would appear to have spread over the *Punjab* during June, July, but mostly in the central and southern districts, the northernmost district reached being Mianwali. The first record of the appearance of swarms in the *United Provinces* is on the 9th July in Agra

district. On the 24th June, however, there is a report of the occurrence of a pink swarm in Chauparan area of Hazaribagh district in Bihar coming from the south-west and passing north-east towards Rajauli area in Gaya district. This would indicate the passage of unreported flights through parts of Central India or through the southern districts of the United Provinces during the early part of June. On the 15th July, a pink locust swarm is reported to have appeared at Gird in Gwalior State coming from the north-east, doubtless from some of the adjoining southern districts of the United Provinces.

To the south-east, some of the western flights reached Wankaner State (States of Western India) on the 27th June coming from the south and Radhanpur on the 5th July from west (leaving northwards).

Summer Breeding

Baluchistan. As monsoon rainfall did not extend into Baluchistan. there was no breeding in summer in Lasbela, Jhalawan, Kachhi or Loralai.

Sind. Monsoon did not reach the Sind area during 1931 except at the end of August in Thar-Parkar district. In fact, there were few swarms to be seen in Sind till the last week of August when some flights reached the desert areas after rainfall. Breeding was not observed in any part of Sind except in parts of Chachro Taluka where hoppers were found in some numbers at the end of September.

Punjab and Punjab States. Swarm movements began in south Punjab on the 9th July in Hissar district and continued in the course of the week following, in Gurgaon, Hissar, Rohtak, Karnal, Ferozepur and Ludhiana districts. The earliest reports of egg-laying were from Gurgaon district on 11th July and from Hissar district on the 14th.

At Delhi the first flight was observed on the afternoon of the 10th July, the swarm disappearing northwards.

In Dera Ghazi Khan, the first swarm was reported on the 11th July. Flights were seen during the month also in Mianwali, Lyallpur, Lahore, Sheikhupura, Multan, Montgomery and Muzaffargarh districts. They were also reported in Bahawalpur, Patiala (Bhatinda, Narnaul, Barnala and Mansa), Nabha, Jind and Faridkot States during July and August.

Egg-laying was observed in Hissar, Gurgaon, Ferozepur, Dera Ghazi Khan, Multan and Montgomery districts and also in Jind, Patiala (Bhatinda, Narnaul, Mansa and Barnala), Faridkot, Nabha and Bahawalpur (Faqirwala) States during July and August. Hoppers were found during August and up to the end of September and the new generation began to fly at the end of August and during September.

United Provinces. The first flight was reported on the 9th July from Agra district. Swarms were reported during July-August mostly from the western districts: Agra, Aligarh, Bulandshahr, Shahjahanpur, Budaun, Mainpuri, Muttra, Moradabad, Kheri, Etah, Bareilly, Saharanpur, Bijnor, Muzaffarnagar, Pilibhit, Dehra Dun, Meerut and Jaunpur.

Eggs were laid in Shahjahanpur, Muttra, Aligarh, Bulandshahr, Bijnor, Muzaffarnagar, Pilibhit, Dehra Dun, Meerut and Jaunpur.

The eastern-most recorded limit of spread was Jaunpur in the middle of August. There is no information on record in regard to locusts after 15th August in the United Provinces.

Rajputana. During June, swarm flights were noticed in Marwar, Jaisalmer, and Banswara. In July, swarms increased in number and were reported from almost all parts of Rajputana and the direction was in general west to east in correspondence with the seasonal south-west winds, though on some days the flights were in the reverse direction following changes in the wind movements.

Egg-laying was first reported in Pargana Nagour in Marwar during week ending 11th July. Hoppers were noticed in Dholpur on 13th July, so that eggs should presumably have been laid here at the end of June. In June-July, the situation was favourable for egg-laying only in the northern parts of Rajputana adjoining Hissar-Gurgaon area, the rainfall being defective in the southern parts (*vide* Pl. 44 Fig. 1). In August, precipitation was heavy all over, especially in south and east Marwar, and breeding was general in many parts of Rajputana, specially heavy egg-laying being reported from the Ajmer-Merwara area. The following were the areas where breeding was reported:—Jodhpur (18 Parganas); Jaisalmer (Jaisalmer, Devikot, Fatehgarh, Lakha, Shahgarh, Lathi, Khuiala); Ajmer-Merwara (54 villages); Kishangarh; Bikaner (Ganganagar, Karanpur, Suratgarh, Sujangarh and Bhadra); and Alwar. Hoppers were abundant throughout September and the majority assumed wings by the end of the month, but in areas of heavy breeding hoppers were still being seen in October.

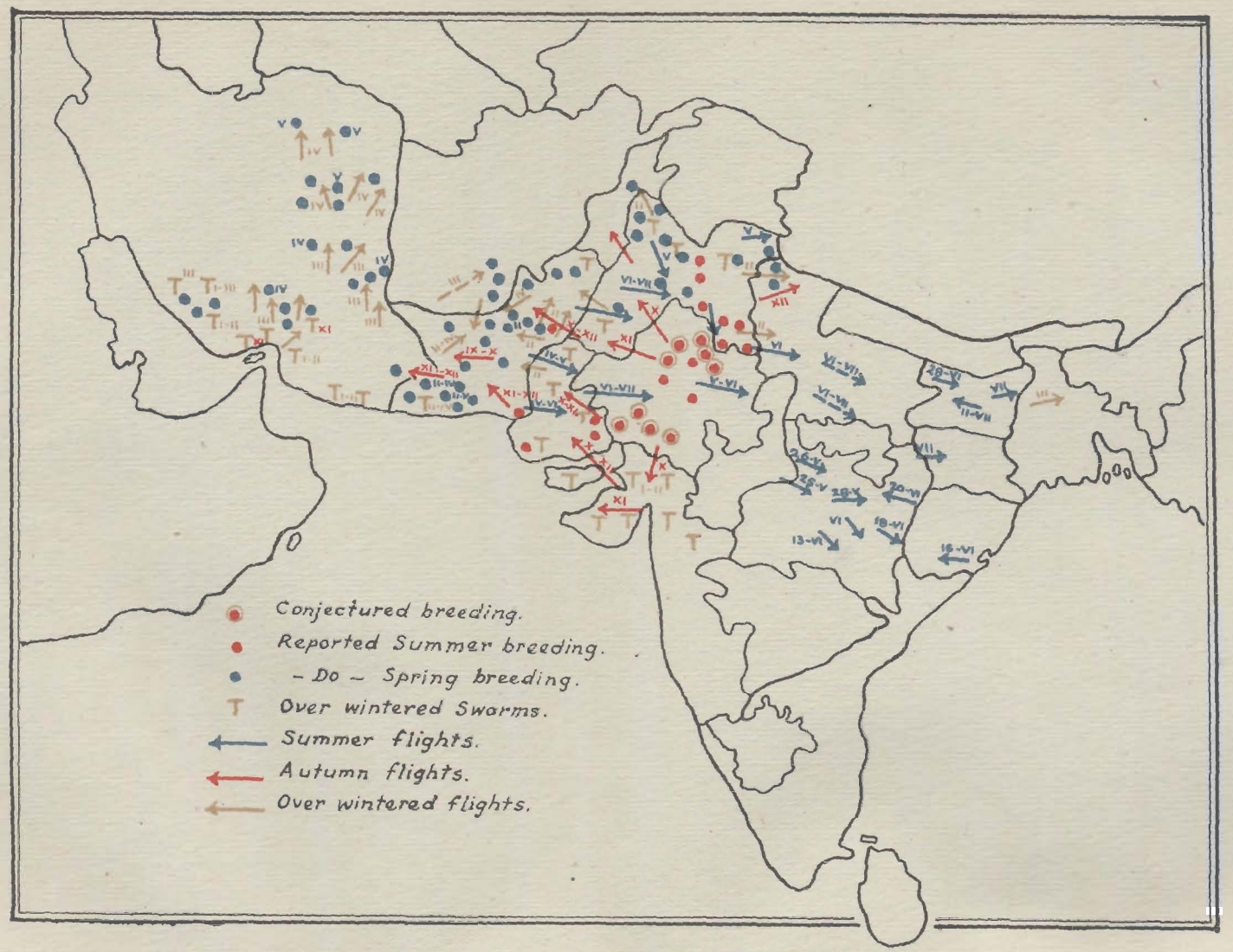
IV. *Autumn 1931* (September-November 1931)

Summer Breeding. As already stated hoppers were being found throughout September and in some areas even in October.

Autumn Flights: Weather Notes. The monsoon current withdrew from north-west India from the 10th September. In the United Provinces, however, after a short break, easterly winds developed from the 18th and good rainfall followed during the rest of the month, as a result of the entrance of depressions from the Bay. During this period easterly winds extended far into Rajputana and the Punjab. Rainfall continued even during the first 10 days of October, during which the easterly currents penetrated the Baluchistan areas also. It was only from the 18th October that the usual westerly autumn winds developed in the United Provinces and Central India areas.

United Provinces, Central India, Central Provinces, Bihar and Bengal. Presumably, it was on account of the unusual development of the easterly winds that, despite a considerable extent of breeding in Rajputana, eastern Punjab and western United Porvinces, there was no trace of the usual eastern migration of swarms that one might generally expect in autumn in United Provinces, Central Provinces and Bihar. Probably such swarms as had been produced in these areas had all taken flight westwards.

The Punjab. Some swarms were active in the central and western districts of the Punjab (Lyallpur, Jhang, Ferozepur, Gujranwala, D. G. Khan, Mianwali, Sialkot and Gurdaspur) during September, the main direction being from the north-west or south-west towards the east. In October, some swarms of medium size would appear to have been active in parts of Chamba State on the 7th and the 8th and to have moved eastwards towards Kangra district on the 9th. It may be presumed that these were part of the swarms that had been reported in Sialkot and Gurdaspur areas at the end of September. There were no further reports of swarm movement for the year 1931, except for one single record of locusts on the 29th October in Dera Ghazi Khan district.



LOCUST SITUATION IN 1927 IN THE INDO-IRANIAN AREA

Rajputana. There were not many records of flights during the autumn months and these were mostly from Jodhpur, Jaisalmer, Alwar, Sirohi (5-6 November, north to south) and Bundi (6th November, west to east). In Jodhpur and Jaisalmer, the general direction was from east to west.

Sind. Numerous flights were recorded in Sind during the months of September, October and November and from almost all the districts of Sind. The general direction was from north-east or east towards south-west,—from Rajputana to Baluchistan. The swarms would appear to have caused much damage to crops in Sind during the autumn months. There were no flights in December except for a pink swarm that visited Kohistan (Karachi district) on the 18th December from Lasbela side.

Baluchistan. Swarms visited Kachhi, Jhalawan, Zhob and Mekran in September. In October and November, reports were mostly from Mekran (Kolwa, Pasni, Parom, Panjgur and Turbat), Lasbela, and Jhalawan (Mashkai), mostly east to west. In December, a fair number of flights were recorded mostly in Jhalawan, Kharan and Mekran, the swarm movements representing the autumn-winter migration towards the west.

Western India States. A flight from south Rajputana appeared at Santalpur on the 25th September and flew away towards Wagad in Cutch the same day. In October, swarms were reported from Bhuj and Khawda in Cutch, from Radhanpur, from Kankrej in Banaskantha Agency and from Malia in western Kathiawar, and in November, swarms visited Tharad and Wao States. These flights had presumably originated from south Rajputana and had been guided south by the northerly or north-easterly winds prevailing in autumn in these parts. There are no records for December.

Summary of Events in 1931: (Pl. 51)

(1) Winter rainfall was late, but fairly good in most parts of north-west India, Iran and East Arabia.

(2) There were no overwintering swarms in the western areas: Baluchistan, Sind, Punjab, and Iran. Swarms were, however, found in the east in Bihar, Central Provinces, Bengal, Assam and Western India States.

(3) Migrants from the west (derived ultimately from Oman) reached Mekran, Kharan and Chagai in April, and spring breeding occurred in Chagai, Kharan, Mekran and Lasbela in April and in Quetta-Pishin, Sarawan and Zhob in May; also in Kandahar area in Afghanistan.

(4) Migration from the western spring brood areas commenced in June and spread gradually from Baluchistan into Sind, Punjab, Rajputana, N. W. Frontier Province, United Provinces, Western India States, Central India and Bihar.

(5) The monsoon was fair, on the whole. There was comparatively poor rainfall in July, but very heavy precipitation in August, in Rajputana and south Punjab. Heavy breeding occurred in the Ajmer and Marwar areas of Rajputana and light breeding in parts of southern and eastern Punjab and western United Provinces.

(6) Fairly heavy autumn flights occurred in Sind and Baluchistan directed westwards in October and November. Southward flights into Western India States also occurred at that period, but there was no eastward migration in autumn.

YEAR 1932

A. Weather Data 1932

I. *Winter-Spring Rainfall 1931-1932*

Winter disturbances began as early as October 1931, but were not fruitful of much rainfall in the winter rain areas. There was some light rainfall between Charbar and Pasni on the coast and in the interior of Baluchistan in December, but with this exception, there was little rainfall in Persia, Eastern Arabia or Baluchistan. In March, however, there was a fair amount of rainfall. Most of the disturbances would appear to have taken a more northerly course and given more precipitation in the interior of Baluchistan in March and April. On the whole, there was drought in most of the winter rain areas.

I. *Monthly Rainfall Data during Winter-Spring* 1931-32: (*in inches*)

1931-1932	Nov.	Dec.	Jan.	Feb.	Mar.	Aprl.	May
Iran.							
Bushire	0·10	0·08	0·43	..	0·47	..	..
Jask	..	..	..	0·10	..	0·80	..
Charbar	..	1·80	0·02	..	0·47	..	..
Seistan	..	0·01	0·29	..	2·22	0·12	..
Meshed	1·44	0·06	3·41	0·54	3·08	1·27	1·7
East Arabia.							
Muscat	0·05	..	..	..	1·34	0·09	..
Bahrein	..	0·05	..	..	1·09	..	..
Baluchistan.							
Pasni	..	0·73	0·06	..	0·15	0·04	..
Panjgur	..	0·09	0·28	..	0·57	0·21	0·1
Turbat	..	0·69	0·14	..	1·56	0·17	..
Sonmiani	..	..	0·18	..	0·08	..	..
Quetta	0·04	0·29	0·41	0·64	1·23	0·29	0·3
Nushki	..	0·15	1·06	0·19	0·56	0·02	0·0
Kalat	0·01	0·05	0·49	0·18	2·09	0·09	0·0
Rindli	..	..	..	.	0·02	..	..
Sind.							
Karachi	..	.	0·10	..	..	..	..
Jacobabad	..	..	0·08	0·02	..	0·05	0·1

II. *Monsoon Rainfall in* 1932 (*monthly data in inches*)

1931	May	June	July	August	September
Baluchistan.					
Sonmiani	..	..	3·85	3·00	..
Ormara	..	..	2·23	0·17	..
Bela	0·24	..	8·86	3·02	..
Rindli	..	..	3·14	..	..
Loralai	0·09	0·33	3·07	3·24	..
Pasni	..	..	5·69	..	..
Sind.					
Karachi	..	..	10·34	0·99	..
Jacobabad	0·10	..	0·70	4·16	..
Mithi	..	..	3·49	3·15	..
Chachro	..	..	6·83	2·45	..

1931	May	June	July	August	September
Rajputana.					
Barmer	0·60	0·45	7·01	2·93	..
Jodhpur	0·13	0·96	1·57	13·91	..
Phalodi	0·18	0·69	1·41	3·02	1·00
Jaisalmer	..	0·14	3·02	3·27	0·18
Bap	..	..	4·99	0·20	..
Bikaner	0·47	0·03	4·79	2·78	..
Nohar	..	0·78	4·71	3·43	..
Jaipur	0·41	0·15	8·16	12·06	0·85
Ajmer	1·03	0·04	3·49	7·59	0·36

A severe heat wave was experienced in northern India in the middle of June. The Bay current of the monsoon extended into N. W. India by the beginning of July. Under the influence of a branch of the Arabian sea current, there was an extension of the monsoon from Kathiawar and Cutch into Sind and Baluchistan which caused heavy rainfall in these areas. Associated with the advance of a depression from the Bay of Bengal, there was further rainfall in the latter half of July in Sind and Rajputana. The activity of the seasonal trough over the Gangetic plain during the first fortnight of August was the cause of heavy precipitation in many parts of N.W. India, including the desert. A break in the monsoon followed from the 15th and lasted till the 28th, but in spite of the resumption of its activity, the Bay current did not extend into Sind and Rajputana, so that in these areas drought practically set in from 15th August.

B. Locust Data 1932

I. *Winter 1931-32* (Dec. 31—Feb. 32)

Few reports of swarms in winter are on record in India. One was reported on the 14th December in Kohistan (Sind) and some from Kharan, Mekran and Jhalawan in Baluchistan during December. In January there was a single report from Panjgur (Mekran) and in February a small swarm was said to have been seen at Kanrach (Lasbela).

Locust surveys carried out in Mekran, Kachhi and Sind showed that fairly numerous, though scattered, locusts were present at various places in those areas during the months of January, February and March. A biometrical examination of specimens collected at this period indicated that they were composed to a large extent of individuals of the *gregaria* and *transiens* phases, showing that they represented stragglers from the autumn swarms passing west-wards over the country. Observations made at Gadap (Karachi district) in March 1932 indicated that such scattered locusts may, under favourable conditions of rainfall, concentrate together in suitable areas for breeding.

Situation in Winter in Arabia and Iran

Arabia. According to Uvarov (1933-a) "several medium sized swarms were observed in the Mecca—Jidda area in October—November 1931, flying mostly northwards or eastwards. Subsequently in November, swarms were encountered further east at the southern edge of the Dahana Desert. In January 1932, considerable numbers of immature locusts were noticed to the south of the Qatar peninsula and in parts of Hasa. In February, large swarms were seen in Hofuf (East Najd) and towards the end of the month the first large swarm passed over Koweit. The invasion of Iraq commenced in February and during March, swarms spread over the Euphrates and Tigris valley, some wandering as far north as Mosul".

"In January, locusts laid eggs apparently over wide areas in the Nefud desert in northern Hedjaj. In April, breeding occurred in several places in the alluvial plains of Iraq, but the hopper bands were small and scattered" (Uvarov 1933-a).

Though there is no definite information, swarms had apparently reached as far east as the Trucial Coast, but in view of the lack of winter rainfall, winter or spring breeding could not have occurred in the Sharja-Barraimi areas in 1932.

Iran. There is information that small pink swarms arrived in the vicinity of Zahidan (Duzdap) on December 30-31, 1931 flying northwards and further flights were observed from the 1st to 3rd January 1932 coming from southwest. Eggs were also said to have been deposited on the sides of the Jaikooli Hill near by, though this appears rather doubtful at the latitude of Zahidan in mid-winter.

A swarm is reported to have passed over Bunder Abbas coming from the east and flying north-north-west on 31st December 1931 and two further swarms to have appeared in the district of Jiruft and Rudbar in south-west Persia during the early part of January 1932. Higher up in the Shiraz-Bushire area, some flights would appear to have been met with at the end of December and the beginning of January at Kazerun.

This would indicate that a small number of swarms—partly derived from India and partly from Arabia,—were roaming about in south-western Persia during the winter months, and would countenance the report made at Turbat by a passing caravan from Persia in February 1932, that egg-laying had occurred in the Bampusht area adjoining Zamuran (Mekran), after rainfall at the end of January 1932. (Sct. III, Chap. 2).

II. *Spring* 1932 (March—May 1932)

Spring Breeding. As there was a general lack of rainfall in Mekran and southern Baluchistan, breeding even of the solitary phase locusts was not noticeable anywhere during the spring of 1932. Green hoppers which were generally met with on the 'Reks' of Pasni, Ormara and Gwadar during April-May, 1931, were not observable anywhere in 1932.

In south Sind, however, in an open area of sandy loam, near Gadap (Karachi district), after the fall of sharp thunder-storm rain on the 24th March 1932, a concentration of scattered overwintered locusts was observed, that led to light egg-laying, from which green hoppers were found later on emerging. It is possible that similar light breeding might have occurred under like circumstances, wherever overwintering locusts were present, as for instance, in the Kech and Panjgur valleys in Mekran.

Incursion of Locusts in Coastal Mekran

Owing to the drought and the lack of breeding, the locust population on the coastal reks of Mekran—Pasni and Gwadar—was found fast decreasing, in fact almost to the vanishing point, during May 1932, when closely following the occurrence on the 24th May of hot dust-storms of great intensity from the north, the appearance of solitary yellow locusts was noticed on many parts of the reks. In the course of the following two weeks, more of the yellow ones were found and later on also pink coloured ones of the true *gregaria* type on the Mekran coast. As these could not have been the outcome of local breeding, it was evident that they had come from a distant place of origin and in the form of a migration flight, not of a swarm, but of a group of individuals [Rao—1936, 1937].

III. *Summer 1932* (June—August 1932)

Summer Flights. The discovery of the entrance of migrating groups of individual locusts in various parts of coastal Mekran and Lasbela and in the Sukkur—Khairpur area of Sind in June has been fully described in Section III. In view of the similarity of the appearance of these incursions with that of typical swarms in these areas both in their general direction and their behaviour, they should be considered to be phenomena of the same type differing only in their relative numbers and degree of activity.

(1) During June there would seem to have been an invasion of locust individuals in all the coastal areas of Mekran, in Lasbela and in western Sind. As these groups happened to be composed mostly of *gregaria* phase forms, they should be considered to have been loose swarms in reality.

(2) In addition there was a report of a small pink swarm about the middle of June near Karachi.

(3) In Bahawalpur State, swarms were observed on the 24, 26, 28 and 29, June in Faqirwali tahsil, passing north to south-east towards Bikaner.

(4) There were three reports from the Western India States Agency:

(i) On 18-vi-32 in Palanpur State north to south.

(ii) On 18-vi-32 at Kerala in Vadia taluk west to east, and

(iii) On 20-vi-32 a red swarm in Wadhwan State east to west.

These presumably represented the south eastern limits of the migration from the west.

It would appear that these loose flights from the western areas had passed over Rajputana at a rapid pace in view of the prevalent heat wave in N. W. India in June and had probably reached the United Provinces and Central India, before the monsoon rains commenced.

(5) With the prevalence of the easterly winds of the Bay monsoon, some of these loose swarms had possibly been carried back westwards.

A very light swarm observed in the Punjab over Nathana (situated on the Ferozepur district and Nabha State borders) on the 26th August might perhaps have been one of such swarms; and a pink swarm seen coming from the north-east in Bilaspur district (C.P.), also on the 26th August might have been another.

Summer Breeding. There was no rain in June, but in July fairly heavy rains were recorded especially in south Rajputana, Sind and Baluchistan. Good rains were received also in August, but there was practically little rain in the desert areas from the 15th August.

The few swarms reported in June would appear to have become scattered in the thick vegetation of the desert after the beginning of the rains, and only breeding of the *solitaria* type is known to have occurred. Apparently, such breeding was wide-spread in Baluchistan, Sind, Rajputana and south Punjab:—in the Pasni Coastal areas, in the interior of Mekran and Jhalawan, in Dera Ghazikhan district and in various parts of the Desert (Thar area of Sind, Mallani, Phalodi, Jaisalmer and Bikaner). As the rains ceased early, there was only a single generation and most of the adults would appear to have emigrated from the desert by the beginning of winter.

IV. *Autumn* 1932 (September—November 1932)

There was only a single report of swarm flight during the autumn from Pirawa in Tonk State on the 5th November. The red coloured locusts are said to have come from the neighbouring Indore and Jhalawar territories, and after staying for a night on the hill nearby to have flown away to the north-east. Apparently these locusts had bred in parts of the Rajputana area.

CHAPTER III

INTERVAL OF 1932—1939

A. THE DECLINE OF THE OUTBREAK OF 1926—1932 IN INDIA

With the summer of 1932, we may consider the cycle of locust infestation that began in June 1926 and continued with a fairly high degree of intensity for a period of six years, to have actually concluded. It should, however, be kept in mind that the Indian outbreak is only part of a much wider infestation affecting three continents, and recent observations have shown that the outbreaks in the different parts of this great area are at least to a certain extent inter-dependent on one another. Although in 1932, few swarms were to be seen in India, the outbreaks in the African areas were still in full swing [Uvarov 1933]. Numerous swarms were active in the Morocco-Senegal and Algeria-Nigeria areas and there was no sign of any decrease in the intensity of the outbreak. In the Sudanese-Arabian area, the infestation was still of fairly considerable intensity, but the breeding in the Sudan area was on a comparatively small scale in summer 1931, and in summer 1932 it was much more reduced, so that in this area also a definite decline had become perceptible.

In the case of the Indo-Iranian area, the linkage would appear to be between the winter-spring breeding in East Arabia, Iran and Baluchistan and the summer breeding in the Sind-Rajputana Desert. As a rule the fliers produced in the spring brood areas migrate at the beginning of summer into the monsoon rain areas and lay eggs in the desert and thus start the summer breeding and the new generation produced in autumn generally migrates by winter into the winter brood areas. It is only when a successful spring brood is followed by an equally abundant multiplication in the summer rains, that the infestation is continued in its full intensity into the coming year. In the Indian area, besides the Sind-Rajputana desert, breeding may also extend in the monsoon period, into the Punjab and the United Provinces, as well as into the eastern States of Rajputana. In these cases, the new generation of fliers generally depart in the autumn in an eastern direction towards Bihar, Bengal and Assam, or in a southerly direction towards Bombay or Madras. Such swarms appear usually to succumb to unsuitable climatic conditions in these areas and are apparently of no value in continuing the infestation. If rainfall either in the winter—spring period or in the monsoon period should fail or be inadequate, there would be a break in the link continuing the outbreak from one year to another, which would bring about a definite decline in its intensity.

In the case of the year 1931, the monsoon breeding was of medium intensity and the autumn swarms migrated in fair numbers westwards and presumably reached Iran and possibly Oman in winter, but owing to the drought that prevailed in the winter and spring of 1932 in Oman and Iran, there was apparently little or no winter breeding in these areas, and consequently very little of migration from Oman either into Persia or Baluchistan. The summer migrants in India in 1932 were very few and the migration assumed the character of a flight of individual locusts rather than of swarms. The breeding that followed in summer in the desert areas presumably took the shape of a scattered multiplication of solitary individuals, so that swarms altogether disappeared.

B. SWARMLESS INTERVAL IN INDIA 1933—1939

From the year 1933 till the year 1940, when a new cycle of locust infestation began in the Indo-Iranian area, there were no swarms of the typical *gregaria* phase in North-West India. In fact, one may

consider the year 1932 to be the beginning of the swarmless interval, though as most of the small summer flights consisted of a high proportion of *gregaria* individuals, the summer of 1932 may also be regarded as the last flicker of the 1926 outbreak.

The autumn of 1932 may be taken to be the real beginning of the regime of the "solitaries". The special organization set up in 1931 by the Imperial Council of Agricultural Research for carrying out field observations on the habits and activities of the solitary phase in N. W. India, had full opportunities of studying the question during a series of years and the results of this work have already been set forth in the earlier sections.

One of the results of these studies has shown that the locust is never in a static condition. It is subtly susceptible to changes in its environment and delicately responds to them so that it is always in a state of flux, at times leaning in the direction of phase *solitaria* and at times in that of *gregaria*. When conditions are favourable, outbreak centres may be formed leading to the development of *gregaria* forms and the formation of incipient swarms, but when conditions requisite for their further development do not obtain, they may simply revert to their *solitaria* form.

It has also been found that even when the locust is in its non-gregarious condition, it is capable, just like the *gregaria* swarms, of migrating long distances from one rain-belt to another at the change of the seasons for purposes of breeding. When conditions favourable for crowded breeding are offered, the locust is able to avail of them at all seasons, and at the same time, when they prove to be adverse, it is capable of tiding over them without much detriment.

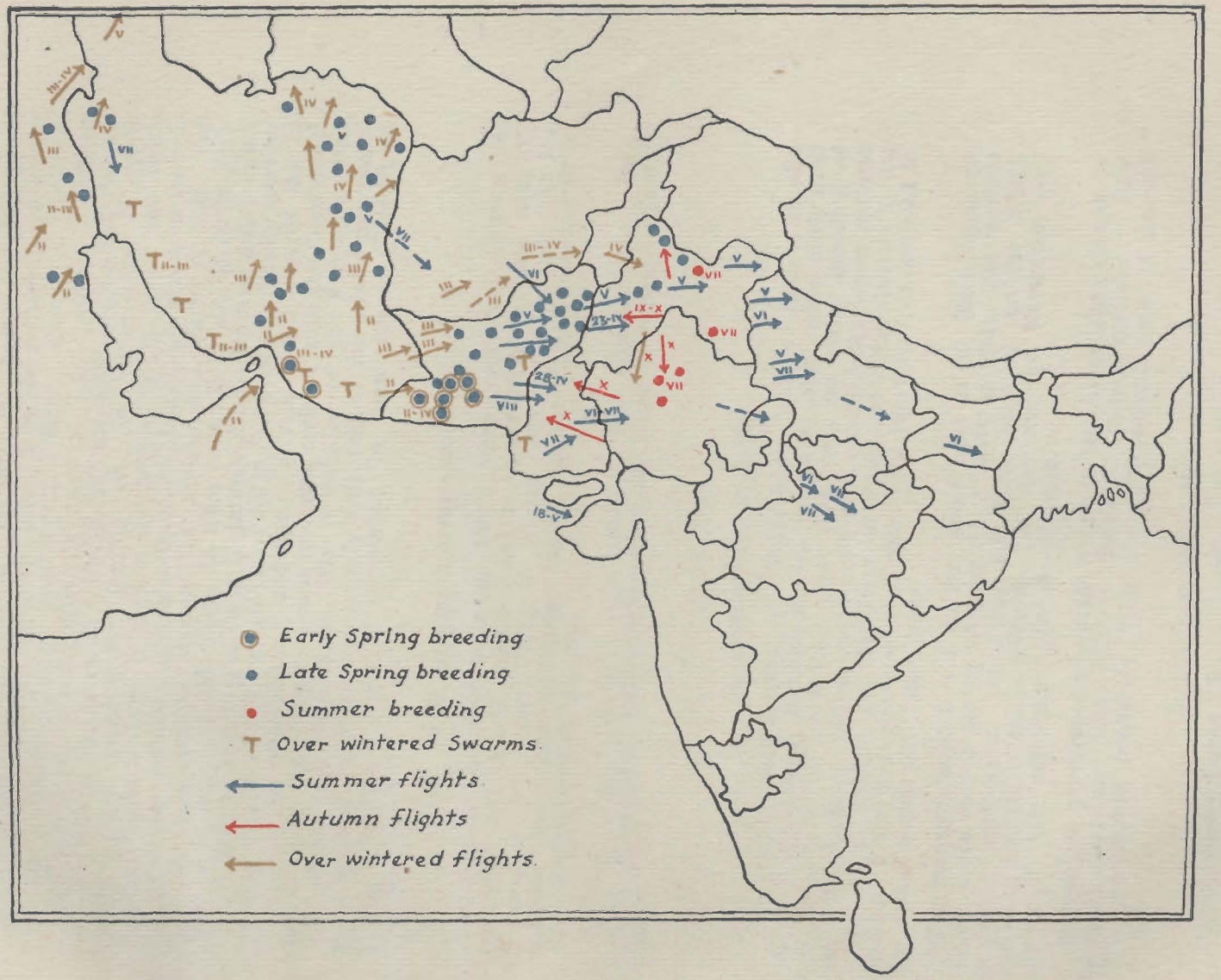
The history of the fluctuations in distribution of the solitary locust and its actual reactions to weather changes season by season and year by year, during this interval, has been fully described in Part I. It is proposed to review in this chapter only such items as happen to relate to the activities of actual or incipient swarms during the years 1933 to 1939.

YEAR 1933

A. *Developments in India*

The winter-spring rainfall was fairly heavy in the Baluchistan area and the breeding of the *solitaria* locust was fairly extensive. The monsoon of 1933 was rather very heavy in most areas. There was fair to heavy rainfall in July in Sind, Gujarat, Cutch and South Baluchistan, while there was heavy and widespread rain in August throughout North India. In many areas there was further precipitation in September.

Observations made by the Survey Staff in the desert areas showed that there was widespread breeding of solitary locusts in most parts of the desert, and large numbers of adults of the new generation were noticed in September and October. No gregarious hoppers were noticed by the staff anywhere nor any flights of regular swarms. Several reports of flights of loose swarms were, however, received by the Locust Bureau of the Imperial Council of Agricultural Research from Bahawalpur, Punjab, Muttra (United Provinces), Bhurtpore, Kotah, Nimar (Indore State), and Western India States. The occurrence of some flights was also reported to the Locust Survey Staff during their tours. Though these flights were not actually investigated, there is little doubt



LOCUST SITUATION IN 1928 IN THE INDO-IRANIAN AREA

that these had actually occurred. As there was heavy and widespread rainfall in the desert, continuous breeding of the solitary phase locusts is known to have occurred, resulting in a large increase of the locust population in the desert. With the onset of dry weather in October at the close of the rains, it is likely that the adult locusts had concentrated in large numbers for feeding on the leafless caper (*Capparis aphylla*) found in large patches in the hollows of the desert and flights of such concentrations might have been the basis of the reports of swarms that had been received during the autumn and winter of 1933. The heaviest breeding would appear to have occurred in the northern parts of the Desert—including Bikaner, Jaisalmer, North Marwar and possibly parts of Jaipur. The direction of winds in October is generally towards north-west in west Bikaner and north Jaisalmer and towards east in east Bikaner and Jaipur, and is in correspondence with the flight direction of the reported swarms. The orientation of the flights reported is, as a whole, in general conformity with that of the swarm movement recorded in typical years of infestation in these areas. (*Vide* Pl. 42 Fig. 2).

B. *Infestation in areas outside India*

In the *Sudanese-Arabian* area, there were very few swarms in the winter of 1932-33 in Arabia and no *winter breeding;* and summer breeding in July-August 1933 in Sudan was very limited. The infestation was, thus, definitely coming to an end. There was little activity in the *Somali* area also.

In the *Morocco-Senegal* area and in the *Algeria-Nigeria* area, swarm movements and breeding were still much in evidence, [Uvarov 1934].

YEAR 1934

A. *Development in India*

The winter-spring rainfall of Baluchistan was a failure, as also that of South Persia and East Arabia except in April, when fairly good falls occurred. In the British areas there was no spring breeding of the solitary phase, but as immigrants of a recently developed *solitaria* brood were noticed in May-June at Pasni and other stations in the Mekran Coast, it is presumed that some light breeding had occurred in the Jask, Charbar and Oman areas.

The monsoon rainfall was on the whole light in the Sind-Rajputana desert areas, except during August when heavy rainfall was received in parts of Rajputana. There was only light breeding on the whole and only a single brood in summer. By the end of November, very few locusts were noticeable in the desert areas.

No swarms were reported except a few in the Ahmedabad district in February and one from Pilibhit district in United Provinces, in July 1934,—presumably connected with the developments noted at the end of 1933.

B. *Situation outside India*

Morocco-Senegal area. Some swarms were found in the winter of 1933-34, but neither spring nor summer breeding occurred.

Algeria-Nigeria area. Spring breeding and flights occurred, but were of much lower intensity than in the previous year: but summer flights and breeding were definitely lighter.

Somali area. There were no activities.

Arabian-Sudan area. There were few swarms little breeding.

Red Sea areas. There was heavy winter rainfall in October—November 1933, which was followed by breeding and the formation of incipient swarms in Tokar and other areas. In November 1934, a loose swarm was noted in Wadi Fatima near Mecca.

South African area. In the early months of 1934, solitary locusts began to form incipient swarms in south-west Africa. Later in the year, some swarms were found in the eastern parts of Cape Colony. Some breeding also occurred in the western areas of the province in December [Uvarov 1935].

YEAR 1935

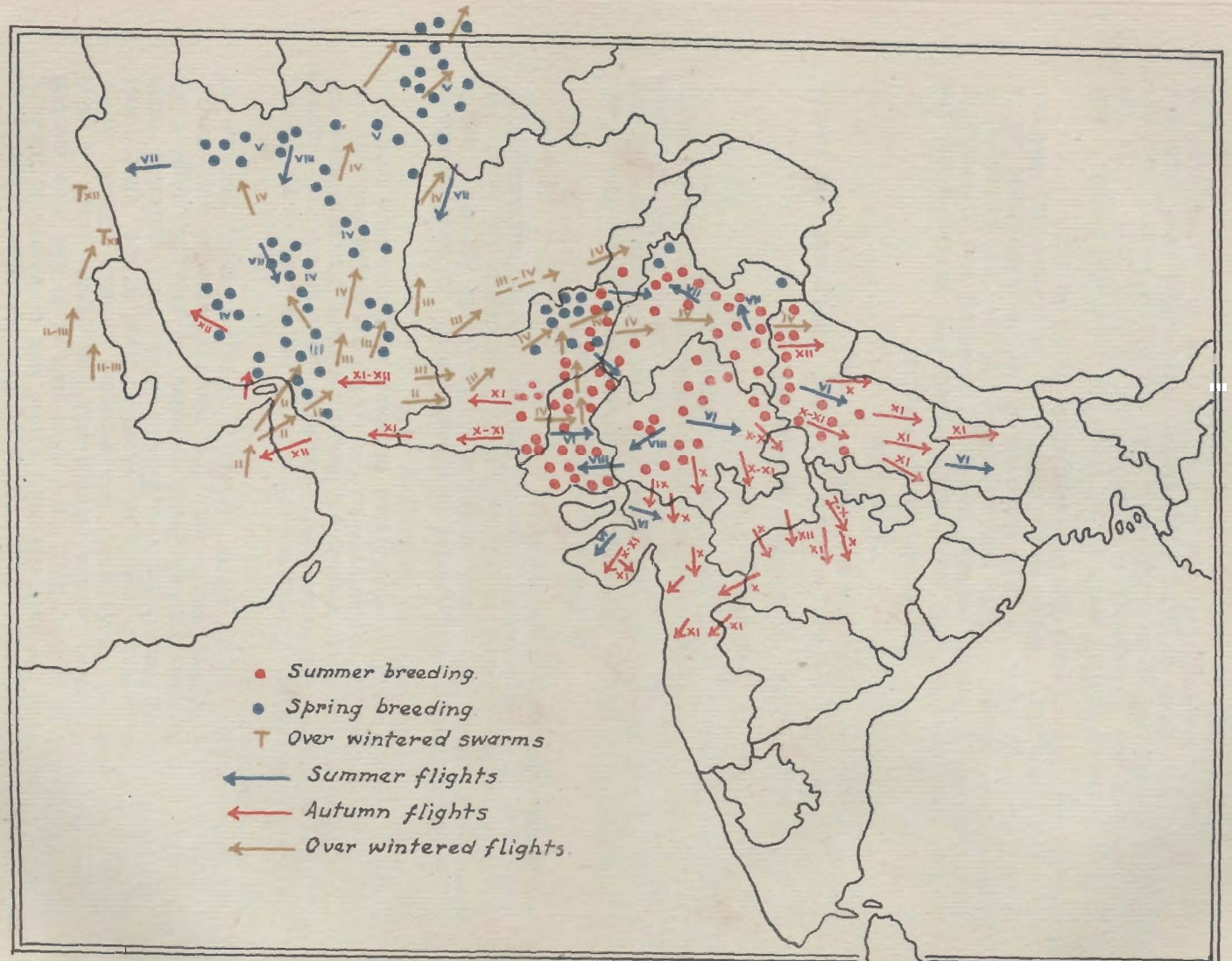
A. *Developments in India*

Winter-Spring Period.—1934-35. The winter and spring of 1934-1935 were characterized by fairly heavy and even copious rainfall in the East Arabian, Iranian and Baluchistan areas. In the Mekran areas where the solitary phase locust was under close observation at several centres, it was found that fairly heavy breeding occurred on the "reks" on the coast between February and April leading to a perceptible increase of the 'solitaria' population. In April-May, there was a migration of the adult locusts from the coastal areas into the interior valleys such as Kech, Kolwa and Panjgur, where in certain, special, ecologically favourable areas, crowded breeding occurred leading to the development of outbreak centres and the formation of incipient swarms by June.

Summer 1935. The monsoon reached north-west India at the beginning of July and fairly heavy rainfall was received in many parts of the desert during the month. From the 23rd July to the 15th August, however, there was a break in the rains in the desert areas. Rainfall in the latter part of August and the first fortnight of September was, on the whole, light except in certain parts of the desert. The monsoon withdrew from north-west India from the 20th September.

Summer Migration. During the early half of July, a heavy incursion of individual locusts was noticed in the coastal areas of Mekran and Lasbela, and also in parts of the Sind-Rajputana desert, such as the Chachro area, parts of Jaisalmer, Khairpur and Bahawalpur States. In fact, even swarms were said to have been noticed as, for instance, on the 4th July at Reti (Bahawalpur State), on 1st July at Shahgarh (Jaisalmer State), and on the 19th July at Faizganj (Khairpur State). It was later on found that such migrant individuals had also arrived in parts of Western Sind, in Karachi and at Nushki in Chagai.

Sample collections of locust specimens from various areas, in which such migrants had been noted, were subjected to biometrical analysis and it was found that the locust population was in most of these cases made up of individuals of different phases: there being a high proportion of phases *gregaria* and *transiens* compared with phase *solitaria*. Most of the individuals, moreover, were of the type with 6 eye-stripes, as is the case in forms composing swarms.



LOCUST SITUATION IN 1929 IN THE INDO-IRAKIAN AREA

The probable origin of this incursion has been discussed by the writer in earlier publications [Rao, 1936 and 1937] and more fully in Section III of this report. While part of this incursion might have been derived from the outbreak centres that had developed in Mekran, there is reason to believe that the greater part of it had been derived from similar centres in Iranian Mekran and East Arabia, since all these areas had received fairly good winter-spring rainfall. There were, moreover, some consular reports in regard to Najd to the effect that an area extending from Riyadh to Koweit had been infested with hoppers and locusts during spring months. It is not improbable that in the area further south—*viz*: the Sharjah-Barreimi area-breeding had similarly taken place, bringing about a great increase of locust population.

Summer Breeding. During a week of fairly heavy rains in the middle of July, eggs were laid in the desert areas and a fair number of hoppers were found on the desert vegetation, but as the rains during August and September proved to be scanty, there was no further oviposition and consequently there was no concentrated breeding leading to the formation of swarms as had happened in the year 1926.

With the normal development of drought in the autumn months in the desert areas, the great majority of the adult locusts—whether remnants of the migrants of July-August or belonging to the new brood developed in the desert—disappeared from the desert migrating westwards into the winter rain areas.

B. *Situation outside India*

Arabia-Sudan area. [Uvarov and Milnthorpe, 1937]. There was some breeding of the solitary phase and the formation of incipient swarms in the spring of 1935 on the Red Sea Coast of Sudan. Summer breeding had also apparently occurred in Abyssinia, between Diredawa and Addis Abbaba. The situation was otherwise quiet.

Morocco-Senegal area. No swarms.

South African area. Light breeding reported.

Evidently 1935 was the first year of calm throughout the Desert Locust habitat in Africa and south-western Asia.

YEAR 1936

A. *Developments in India*

The winter-spring rains were fairly good, but on the whole the total rainfall was below average, and spring breeding was consequently light in most places. There was an instance of incipient swarming in Kolwa in March-April. A light incursion of locust individuals of a new generation from outside was observed in May-June in Mekran, which ultimately reached the Sind-Rajputana desert in June.

The monsoon rainfall commenced early in June, and rainfall was fairly heavy and widespread in the early part of July, and fairly extensive breeding of *solitaria* followed. At this period several instances of locust individuals carrying 8 eye-stripes were noted—and thus may be regarded to a certain extent to be the *climax* in the development of the *solitaria* phase.

There was a break in the rains extending over a period of nearly 4 weeks, but in the second week of August, there was heavy rainfall at many places in the northern areas of the desert, as a result of which fairly heavy breeding occurred in these areas. Breeding continued

here even into November, as a result of which numerous overwintering locusts were found in these areas during December and January. But, as usual, the adults of the early generation migrated out of the desert during September-October on the development of dry weather conditions characteristic of early autumn.

No *swarms* were seen anywhere during the year.

B. *Situation outside India*

There were no reports of swarms or breeding in 1936 in the *Morocco-Senegal* area, nor any in the *Somali* area [Uvarov and Milnthorpe, 1937—a].

In the *Algerian-Nigerian* area also there were no signs of swarms except for a few reported from the Niger Colony in June-July.

In the *Arabia-Sudan area,* there was spring breeding in March-April, 1936 in the Red Sea coast of Sudan. Again in October 1936, there was heavy rainfall in Tokar Delta in the Red Sea Littoral, as a result of which egg-laying by scattered swarms coming from Eritraea took place, and scattered hopper bands developed. Young fliers developed from these bands; and by December, the second winter generation of hoppers had emerged. Further swarms also invaded the area from outside in December and oviposited in parts of the Tokar Delta. Hoppers continued to appear till February and March 1937, but most of them were destroyed by control measures.

This may possibly be regarded as an early indication of the development of a new outbreak.

South-African area. No developments.

YEAR 1937

A. *Developments in India*

Rainfall in the winter-rain areas was rather peculiar. In the coastal areas of British and Iranian Mekran, rainfall was very light but in the hinterland as in the interior valleys of Mekran and in Kachhi and Lasbela, there was greater precipitation.

On this account, little breeding was seen on the coastal areas, and the locusts that were present there early in winter were found to have migrated into the interior and to have concentrated there in spring. In the interior of Lasbela an outbreak centre developed near Sheh Lakhra, and in Kachhi, large concentrations of hoppers were found to have developed in Kachhi and Bolan areas.

Locusts produced in these areas, as also others originating in possibly similar breeding grounds in Iranian and Arabian territories, reached the desert areas by June-July.

The monsoon extended its influence into north-west India by the end of June, and in July fairly heavy rainfall occurred in most parts of the desert. The eastern parts of Bikaner shared in this rainfall, whereas the north-western parts and the greater part of Jaisalmer did not get any rain. Rather concentrated breeding was, thus, observable in the eastern tahsils of Bikaner. Extensive multiplication occurred in the southern parts of the Desert also, *viz*: Thar and Mallani.

There was a long break of nearly 5 weeks in the monsoon in August—September and owing to the unusual drought during this period, large displacements of flying locusts occurred, which in one case, *e.g.,* at Sardarshahr, assumed the shape of a swarm. While the greater number of locusts produced in the desert migrated, a certain number over-

wintered, especially in the southern desert, where late breeding had occurred.

One of the main characteristics of the breeding of 1937 was that although the solitary phase was dominant, most of the locusts possessed 6-striped eyes, as contrasted with 1936, when 7-striped forms were greatly in evidence.

B. *Situation outside India*

Arabia-Sudan area.—January-February 1937. The adult locusts that developed from the hoppers of December 1936 brood flew away to the east.

April 1937. A swarm was reported in Transjordan (probably derived from the Red Sea areas).

June 1937. An outbreak of the Desert locust occurred in the northern part of the Western Desert of Egypt, subsequent to heavy rains received in April [Uvarov and Milnthorpe 1939]. No reports of swarms from other areas.

YEAR 1938

A. *Developments in India*

Winter-Spring rainfall in the Baluchistan-Iran areas was moderate. The amount of rain received varied at different places, but the total was below average everywhere. There was light to moderate "*solitaria*" breeding on the coastal areas and also in the interior valleys of Mekran.

The monsoon began early in June; and in July there was general rainfall all over the desert, but in August the rainfall was defective and, in September, it proved a failure. There was light summer migration of solitaries from the west in Baluchistan and the Sind-Rajputana desert. Breeding began early in the desert areas, but was quite limited in extent owing to the defective rainfall. With the onset of dry weather in September, the few adults produced in the desert left the area, so that locusts were completely absent in these areas in winter.

B. *Situation outside India*

Sudan-Arabian area.—January-February 1938. Hoppers of the gregarious phase derived from oviposition by an invading swarm from outside were found on the Red Sea coast of Sudan.

February-March 1938. Breeding was reported from the Halaib area, [Uvarov and Milnthorpe 1939].

There were no reports of locust swarms from the other areas.

YEAR 1939

A. *Development in India*

There was fairly heavy rainfall almost all over the Baluchistan area during winter and spring, and rather unusually heavy rain in February and March in Lasbela and Kachhi. Winter rainfall was comparatively light in the Iranian and east Arabian areas. The solitary locust population was rather thin in the winter-spring months in Mekran and there was, therefore, only light breeding in spring. In the interior of Mekran, there were no locusts in winter, but in spring fair numbers were found and fairly heavy breeding would appear to have occurred in May-June and July, in Kulanch, Kech and Kolwa areas. There is little doubt that these might have developed into "out-break centres" if there had been a large initial population in spring.

A fair amount of 'solitaria' breeding took place in the Lasbela area in view of the unusually heavy spring rainfall. Heavy breeding also occurred in the Kachhi and Bolan areas in May-June.

The monsoon of 1939 was very defective like the year previous. Fairly good rainfall occurred in June and July in the northern areas of the desert and stimulated light summer breeding, which continued till the middle of September, but in the southern areas there was little rain till the last week of August when heavy falls were received, but there was little breeding even after the rainfall. Breeding was, on the whole, scanty in the desert and no locusts were found in November and December.

B. *Locust Situation outside India*

There were apparently no locust swarms in any of the African and Arabian areas during the year, but according to Pasquier, [1942], a heavy patch of infestation and incipient swarming was discovered (10th May, 1939) in Mouydir, in the southern territory of Algeria. It was reported that most of the hoppers succumbed to the intense heat of the climate and that the adults of the hoppers that survived left the area for more southerly regions by August. Light to moderate breeding is said to have occurred in the Hoggar, Adrar and Air areas in south Sahara in summer. Scattered locusts or loose swarms are said to have been found in Mouydir and Tidikelt at the beginning of 1940, but there was little breeding on account of drought.

DISCUSSION

Prior to 1930 when investigations on the solitary phase were started in several countries, though it was well recognised that the desert locust did not really disappear altogether during the period when swarms were not noticeable, but existed in the deserts in the form of scattered solitary individuals, there was no definite knowledge as to how exactly the solitary phase locusts lived and reacted to the changes of seasons and climate during the swarmless interval. As a result of continuous detailed observations on the ecology of the solitary phase during a series of 8 years in the Indian area, a fairly full knowledge of its habits and activities has been obtained. A summary of the history of the activities of the solitaries during the years 1932 to 1939 has been given in the above notes, which will serve to indicate generally what might possibly have happened during any of the swarmless intervals intervening between the various locust cycles of the past.

One of the results has been to show that during these quiet intervals, the activities of the *solitary* locust are essentially of the same character as those of the *gregaria* form. It responds quite similarly to the changes in its environment, breeds more or less under similar conditions, and migrates long distances under the stimulus of more or less the same environmental factors. Just as the locust swarms migrate from the winter rain belt to the summer rain areas and *vice versa* in search of conditions favourable for breeding, so do the *solitaria* locusts, which thereby secure the development of at least two generations in the year. The main difference between the activities of solitaries and swarms would appear to be in the comparative degree of intensity.

It is also evident that all the individuals of the locust population found in any particular area are not always in the same state of development in regard to phase. Desert areas are generally subject to large fluctuations of climatic conditions and rainfall, which are often quite

local so that all the individuals of the locust population do not come under the influence of such changes to the same extent. For instance, it is only those locusts that reach areas favourable for the development of outbreak centres that undergo a transformation of phase, while the rest continue to remain in the solitary phase. On the other hand, *gregaria* phase locusts on reaching an area of lush vegetation, such as may be found occurring in parts of the Rajputana Desert after the fall of heavy monsoon rains, tend as a general rule, unless they are in large swarms, to revert to the *solitaria* condition; for small bands of hoppers, or small swarms of adults, on reaching such areas, are apt to lose their individuality when they get distributed among the dense plant growth. If the vegetation should, on the other hand, prove to be sparse or happen to consist of scattered green patches, there are greater chances of locusts forming concentrations and laying eggs in crowded masses and of groups of *gregaria* hoppers retaining their individuality as bands.

Even in years of swarm activities, the *solitaria* type of breeding would also appear to occur at places, independent of the appearance of swarms, and sometimes even side by side with or in sites quite adjacent to areas of *gregaria* breeding. Whereas it is only the occurrence of hopper bands or of swarm flights that attracts the attention of the general public, the presence of isolated hoppers or of solitary locusts is never likely to be noticed by people unless they happen to be specially interested in the locust problem. Consequently even scraps of information available with reference to the activities of swarms or the occurrence of gregarious breeding for years of locust quiescence should be welcomed, as they are likely to give valuable clues in regard to locust developments in such years, when examined in the light of the general scheme of locust activities obtainable from the detailed studies of the recent interval of 1932-1939. Just as fossils found in sedimentary rocks serve to give valuable clues in regard to the life and conditions of a past geological age, a study of these data may give useful hints in regard to the development of past outbreaks.

During the recent interval, the following were the outstanding reports in regard to *gregaria* developments in India: (1) occurrence of swarms in the summer of 1932, (2) movements of swarms in the autumn of 1933, (3) incursion of swarms in the summer of 1935, and (4) mass-multiplication of hoppers in Kachhi and Bolan in 1937. These are seen to be capable of explanation by a study of the observations made on locust developments in correlation with rainfall and other meteorological data. While the autumn swarms of 1933 were evidently caused by the unusually good and continuous monsoon rainfall in the desert, the summer swarms of 1932 and 1935 were in great part due to an incursion of locusts from the winter rain areas of Baluchistan, Persia and East Arabia. The heavy breeding of locusts in Kachhi in 1937 was due partly to a concentration of locusts from the areas of unusual drought on the coast and partly due to favourable rains and floods in the Kachhi area. It may be possible, to a certain extent, to explain in this way, the scrappy information available for past swarmless intervals also, with the help of meteorological data, but there is often the complication due to the arrival of locusts from outside India, of the antecedents of which it is not possible to make any statement in the absence of positive data.

It is now proposed to examine the swarmless interval 1920—1925 which preceded the last great period of locust outbreak in India (1926—1931) in the light of the experience gained during the recent interval.

CHAPTER IV

INTERVAL 1920—1925

DURING 1919, swarms were found in spring and summer in Upper Baluchistan and breeding occurred in various places. The usual western migration was signalled in Sind and the Punjab in May, but no further data are available. Apparently, the migration being feeble, locusts reverted to the "solitaria" phase in the desert.

YEAR 1920

A. WEATHER NOTES

I. *Winter-Spring Rainfall* 1919-1920: (*Data in inches*)

1919-1920	Nov.	Dec.	Jan.	Feb.	March	Apr.
Iran						
Jask :	..	2·67	2·08	1·78	0·44	..
Arabia :						
Muscat	..	..	0·25	0·54	0·03	..
Baluchstan :						
Pasni	..	1·15	3·68	0·17	0·32	..
Panjgur	..	0·38	1·34	0·29	0·80	..
Quetta	.	0·92	0·89	1·12	1·61	0·8
Nushki	..	1·51	1·00	2·87	2·12	..
Sind						
Karachi	..	..	..	0·41	..	..

II. *Monsoon Rainfall* 1920: (*Data in inches*)

1920	May	June	July	Aug.	Sept.
Sind.					
Karachi	0·33	..	0·16	..	..
Mithi	1·13	2·06	3·08	1·75	..
Chachro	0·85	0·45	1·63	2·35	..
Rajputana :					
Barmer	3·25	0·54	2·00	3·95	..
Jodhpur	2·95	4·62	3·16	0·44	..
Jaisalmer	3·33	0·40	2·24	4·57	..
Bikaner	0·85	4·99	5·59	0·76	..

B. LOCUST DATA

1. *Winter-Spring* 1920: No records.

2. *Summer* 1920: *Baluchistan.—June.* Locusts are reported to have appeared in Zhob district at Girda Babar in the beginning of the month and to have done some damage to standing crops. In Loralai district, locusts were prevalent in June in Barkhan tahsil.

Punjab. During week ending 20th July 1920, crops were slightly damaged by locusts in Mailsi, Multan district.

(NOTE.—These reports presumably refer to small summer flights that had taken place from the west).

3. *Autumn* 1920. No records.

Summary of Events in 1920

Winter-spring rainfall was satisfactory in south Persia, and led presumably to light spring breeding there. A few western flights were seen in Baluchistan and Punjab in June-July.

The monsoon rainfall was early and was fairly widespread in the desert, and *solitaria* breeding probably occurred. No rain in September and early autumn flights of *solitaria* possibly occurred.

YEAR 1921

A. WEATHER NOTES

I. *Winter-Spring Rainfall* 1920-1921: (*Data in inches*)

1920-1921	Nov.	Dec.	Jan.	Feb.	Mar.	April
Iran :						
Jask	..	0·04	..	0·02	..	.
Arabia :						
Muscat	0·16	..	0·17	..	..	.
Baluchistan.						
Pasni	..	0·10	0·18	..	..	..
Panjgur	..	0·02	..	..		..
Quetta	..	0·24	0·55	0·20	..	0·66
Nushki	..	0·62	0·47	..	..	..
Sind :						
Karachi	..	0·20	..	..	..	..

II. *Monsoon Rainfall* 1921: (*Data in inches*)

1921	May	June	July	August	September
Sind:					
Karachi	..	..	7·70	7·14	..
Mithi	..	..	9·70	2·06	4·66
Chachro	..	..	13·69	0·60	4·20
Rajputana:					
Barmer	..	..	9·04	0·36	6·55
Jodhpur	..	..	3·30	1·93	..
Jaisalmer	..	..	1·41	0·60	0·59
Bikaner	..	0·49	9·46	4·52	1·75

B. LOCUST DATA.—No records.

Summary for 1921

The winter rainfall was a thorough failure. Apparently there was little of *solitaria* breeding. The monsoon began late but was fairly copious except in Jaisalmer and extended into September. *Solitaria* breeding possible, and as there was good *rainfall in September*, late breeding could have occurred.

YEAR 1922

A. WEATHER DATA

I. *Winter-Spring Rainfall* 1921-1922: (*Data in inches*)

1921-1922	Nov.	Dec.	Jan.	Feb.	Mar.	April
Iran :						
Jask	2·88	0·86	0·23	1·76	..	..
Arabia :						
Muscat	0·98	0·61	0·17	0·25	..	..
Baluchistan :						
Pasni	0·92	3·59	0·89	0·26	..	..
Panjgur	..	3·83	0·26	1·01	0·06	..
Quetta	0·30	3·17	1·31	1·40	0·08	0·12
Nushki	0·41	1·77	0·83	1·02	0·90	..
Mithri	..	1·61	..	..	..	..
Loralai	..	4·04	..	0·06	0·56	0·26
Sind :						
Karachi	..	0·78	..	0·23	..	..

II. *Monsoon Rainfall* 1922: (*Data in inches*)

1922	May	June	July	Aug.	Sep.
Sind :					
Karachi	..	..	0·19	1·43	0·17
Mithi	..	..	1·95	1·20	1·65
Chachro	..	..	1·64	2·62	3·53
Rajputana :					
Barmer	0·45	..	1·93	2·06	3·91
Jodhpur	0·17	0·25	5·93	0·73	3·34
Jaisalmer	..	..	2·25	1·26	1·33
Bikaner	..	..	1·40	1·20	1·67

B. LOCUST DATA

I.—*Winter* 1921-22. No records.

II. *Spring* 1922. During December 1921, good rainfall occurred in the Kachhi area and as at the same time heavy rain fell in Loralai district in the interior, the Kachhi plain had evidently received good

floods by the overflow of the Nari river. There were reports of egglaying and of the emergence of hoppers during April in the Bhag niabat of Kachhi. During May there was complaint of damage by hoppers and adults to the late spring crops (jowar). Similar damage was also reported from the Mirpur-Nasirabad and Gandhawa niabats. During June, damage by adult locusts was reported from several places in Mirpur-Nasirabad.

III. *Summer* 1922. In June, July and August, a few reports of damage by locusts were received from the Kachhi area. In August, considerable damage to crops by locusts was said to have been caused in Kohlu tahsil of Sibi district.

In the Dera Ghazi Khan district of the Punjab, locusts are reported to have done much damage to *jowar* and *bajra* in the Sanghar Tahsil in August 1922.

IV. *Autumn* 1922. Locust damage to jowar crops in early September was reported in Dadhar and Gandhawa niabats of Kachhi and in Takht Mir Circle of Bolan, and in November damage to *jowar and sarshaf* in Sibi district.

Summary of Events in 1922

The winter-spring rainfall was fairly heavy in December 1921 and moderate in February.

There were probably locust concentrations in March in Kachhi made up of over-wintered locusts derived from late breeding (1921) in the desert, and in view of the good rainfall in December 1921, breeding would appear to have started by March-April 1922.

In June-July, western immigrants would appear to have arrived in Kachhi and Sibi in Baluchistan and Dera Ghazi Khan in the Punjab.

The monsoon rainfall was moderate, but there was precipitation in September. It is probable that some *solitaria* breeding had occurred in the desert. Small autumn flights were observed in Kachhi and Sibi.

YEAR 1923

A. Weather Notes 1923

I.—*Winter-Spring Rainfall* 1922-23: (*Data in inches*)

1922-1923	Nov.	Dec.	Jan.	Feb.	March	April
Iran:						
Jask	..	1·85	0·69	0·82	0·01	1·68
Arabia:						
Muscat	..	..	0·26	0·30	..	1·44
Baluchistan:						
Pasni	.	0·07	1·41	0·82	0·36	0·21
Ormara	..	..	3·00	4·50	..	..
Panjgur	..	0·12	0·57	0·53	0·21	0·11
Turbat	..	0·68	0·51	1·53	0·27	0·95
Quetta	..	0·91	2·60	1·69	1·21	0·68
Nushki	..	0·24	1·85	0·70	1·09	1·09
Loralai	..	0·60	0·78	1·06	1·30	1·25
Sind:						
Karachi	..	..	0·31	1·11	..	..

II.—*Monsoon Rainfall* 1923: (*Data in inches*)

1923	May	June	July	Aug.	Sept
Sind :					
Karachi	..	..	0·17	3·49	..
Mithi	0·65	..	0·72	5·05	..
Chachro	0·80	..	0·55	3·10	..
Rajputana :					
Barmer	0·23	..	1·66	1·59	..
Jodhpur	0·34	0·01	9·65	8·65	..
Jaisalmer	0·26	..	1·90	5·68	0·15
Bikaner	1·54	1·45	4·63	3·08	0·21
Baluchistan :					
Mithri	..	..	1·19	4·17	..
Loralai	2·83	..	1·89	2·69	..

B. Locust Data

I. *Winter* 1922-23. No data available.

II. *Spring* 1923. The earliest record about the occurrence of locusts is in the diary of the Naib of Pasni in Mekran for the first fortnight of May 1923. Locust hoppers were said to be damaging the standing crops of *sohru* (Red Jowar), pulses and cotton in the villages of Zarren Bug and Hasadi on the banks of the Dasht river. At the end of May the hoppers were reported to be in innumerable numbers and to be spreading from Hasadi Mauza up to Gabd, very near the Persian frontier. At the end of June, they were said to be in millions and "after eating the ears and leaves, to be now eating the stems" of jowar. During June, hoppers were acquiring wings and by early July the winged locusts were leaving the fields and flying towards the jungles. It was reported that some locusts had also appeared in summer 1923 near Ormara.

III. *Summer-Autumn* 1923 (*June-November* 1923). By the end of July, most of the adults produced in the Dasht valley had flown away from that area.

By the third week of July, locusts were reported to be present on jowar crops in Dadhar niabat of Kachhi. In August, locusts were still found on crops; good rain appears to have fallen during the latter half of August; and during September, "small locust hoppers" would appear to have been found in Dadhar niabat, and later on, in October, in Mirpur-Nasirabad niabat damaging the crops. It is possible that breeding had occurred in these areas after heavy monsoon rainfall.

In regard to the spring breeding in the Dasht valley, the writer had in an earlier publication considered it to be a case of incipient swarming, as the result of crowded egg-laying by the adults of the first spring generation produced on the coastal reks by over-wintered solitary locusts [Rao, 1933]. An examination of the rainfall data of the winter rain areas in Baluchistan, Iran and Oman would show, however, that the rainfall in general had been defective and could not have induced any extensive breeding in January-February in any of these areas. It is more probable that the breeding had been caused by the incursion of fairly large numbers of over-wintered locusts from the direction of Iran during April. The

area where breeding had occurred was along the banks and on the bed of the Dasht, presumably on the high flood terraces of alluvial soil on which fertile crops are usually raised. As good rainfall had occurred in the Kech valley in February and April, normal floods had presumably occurred in the Dasht river and conditions should have been favourable on the river-bed for egg-laying and hatching. It may also be supposed that locusts had concentrated on the riverine area owing to the prevailing drought outside.

Good rainfall is known to have occurred in the winter of 1921-22 in the Red Sea area of Sudan (Suakin 180 mm. October—February) and possibly good rain had fallen also in the Arabian and Eritrean regions presumably inducing breeding in those areas. Since in Kermanshah in Persia also an entry of locusts from the west had been reported in 1923, the locusts causing the Dasht infestation might as well have been of Arabian origin.

Locusts seen in Dadhar in Kachhi in July-August were probably derived from the Dasht infestation or might have been part of the usual *solitaria* migration from the west in summer.

The monsoon began early by middle of May in N. W. India; there was little rain in June except in Bikaner, fairly good rainfall occurred in July and heavy falls in August and little rain in September. *Solitaria* breeding had possibly occurred in the desert in summer.

Summary of events in 1923

Winter-spring rainfall was defective but concentrated breeding occurred on long stretches of the Dasht river-bed in April, and hopper infestation was reported from May to the beginning of July.

During summer (July-August), locusts appeared in Kachhi (Dadhar) and damaged crops. In September-October, light breeding presumably occurred in Dadhar after heavy rain in August.

Monsoon rainfall was fairly good: *solitaria* breeding might have possibly occurred.

YEAR 1924

A. Weather Notes 1924

I. *Winter-Spring Rainfall* 1923-1924: (*Data in inches*)

1923-1924	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Iran:						
Jask	0·61	..	0·25	0·04	..	..
Arabia:						
Muscat	1·55	..	0·10	0·21	..	..
Baluchistan:						
Pasni	..	..	..	0·70	..	1·47
Ormara	..	..	..	1·00	..	0·14
Panjgur	..	..	0·05	1·92	0·05	1·78
Turbat	..	..	..	3·35	0·49	1·19
Quetta	..	0·13	1·99	2·45	0·73	2·28
Mithri	..	..	..	2·32	..	..
Loralai	..	..	0·15	2·87	0·75	2·95
Sind:						
Karachi	..	..	..	0·61	..	..

II. *Monsoon Rainfall* 1924: (*Data in inches*)

1924	May	Jun.	Jul.	Aug.	Sept.
Sind:					
Karachi	..	..	1·82	0·08	..
Mithi	..	0·58	2·86	4·37	1
Chachro	..	0·28	7·61	4·66	3
Rajputana:					
Barmer	..	0·71	3·35	1·84	5
Jodhpur	0·77	0·79	4·98	2·22	12
Jaisalmer	0·62	..	3·91	0·29	2
Bikaner	0·98	1·38	1·05	2·37	

B. Locust Data 1924

I. *Winter* 1923-24. No records.

II. *Spring* 1924. Between the 19th and 27th April, large numbers of locusts were reported to have been found in several villages of the Bhag niabat in Kachhi. They were said to have been damaging the *sarshaf*, *jambha* and jowar crops, and it was stated that "all the paths had been covered with locusts."

On the 3rd May, Naib of Bhag reported that "Poong" (Hoppers) had hatched out in very large numbers in Mauza Audra Qadir Bux and that they were damaging "the wheat that had been reaped, heaped up and blown."

According to Jhanjhua [1940] the nymphs of the "Black-headed cricket" *Gryllulus domesticus L.* also similarly "attack the sheaves of the stacked Colza, Rocket and wheat crops" in Nasirabad tahsil and it is not certain if the Naib of Bhag had these in mind in the report made by him.

III. *Summer* 1924. No records.

IV. *Autumn* 1924. In the middle of November, the Naibs of Gandhawa, and Lahri reported that locusts had been damaging late jowar, pulse, *sarshaf* and *jambha* crops.

Summary of Events in 1924

(1) The winter-spring rainfall was poor in Iran and Oman, but fairly good in Upper Baluchistan and the Mekran interior, especially in February and April. Good rain fell in Kachhi in February.

(2) Locusts were reported in April and May in Bhag Niabat, and hoppers (*poong*) were also said to be found, but it is not certain if the reports were referable to the black-headed cricket.

(3) The monsoon rainfall was both early and fairly copious in the desert. *Solitaria* breeding was quite likely and late breeding might also have occurred.

(4) Locusts were found in parts of Kachhi in November and this might be representative of the autumn movements of 'solitaries'.

YEAR 1925

A. Weather Notes 1925

I.—*Winter Spring Rainfall* 1924-1925: (*Data in inches*)

1924-1925	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Iran :						
Jask	..	4·18	0·89	..	0·13	..
Arabia :						
Muscat	..	0·73	0·27	0·06	0·19	..
Baluchistan :						
Pasni	..	0·26	1·99	1·15	..	..
Panjgur	..	1·03	0·11	0·27	0·03	..
Turbat	..	0·44	1·09	0·07	..	..
Quetta	0·05	2·05	0·44	0·35	0·98	..
Loralai	..	0·45	..	0·73	0·12	..
Sind :						
Karachi	0·75	..	..	..	..	..

II.—*Monsoon Rainfall* 1925: (*Data in inches*)

1925	May	Jun.	Jul.	Aug.	Sept.
Sind :					
Karachi	.	1·95	0·88	1·12	..
Mithi	..	3·71	0·44	0·71	0·03
Chachro	0·70	2·65	0·50	1·07	..
Rajputana :					
Barmer	..	0·05	1·48	0·05	..
Jodhpur	..	1·74	2·70	0·36	..
Jaisalmer	0·30	0·32	0·93	0·91	..
Bikaner	1·90	2·06	2·18	..	04·0

B. Locust Data, 1925

I. & II. *Winter-Spring* 1925.—No records.

III. *Summer* 1925.—Locusts ("Tiddi") were reported damaging crops in the Bhag Niabat of *Kachhi* during week ending 30th June.

In the Punjab, "Tiddi" damage to jowar and bajra crops in Sanghar and Dera Ghazi Khan tahsils is recorded in the Crop Reports of the Director of Land Records in Punjab.

IV. *Autumn* 1925. No information.

Summary of Events in 1925

(1) Winter rains were moderate except in December 1924. Jask had the highest monthly rainfall—4·18 in., in December.

(2) Only light "solitaria" breeding possible.

(3) The presence of locusts in Kachhi and Punjab was possibly a sign of summer migration from the west.

(4) Monsoon began early in the desert in May, there was fair rainfall in June, little rain in July except in Bikaner and east Marwar. Rains ceased by the middle of August, so that the desert suffered from a heavy defect of rainfall.

(5) Only light breeding should have been possible.

The year which followed, *i.e.* 1926, was the first of a new cycle of infestation in India. A review of the occurrences in regard to locust developments during 1925, would show that the commencement of the new outbreak had been very little influenced by the events of 1925. There could not have been such a large over-wintering population of *solitaria* in January in the Indian areas as to start a new cycle. It is evident that influences emanating from outside India should *have played a great part in bringing* it into being.

SECTION VIII—PERIOD 1908 TO 1919

CHAPTER I

INTERVAL 1908—1911

The year 1907 was the last of a long series of years of infestation in India, beginning from 1889, in which there was hardly a single year completely without swarms.

The year 1907 was marked by fairly good spring breeding in parts of the Punjab, the N. W. Frontier Province and Baluchistan, followed by summer flights from the Punjab and the west reaching Bihar and Bengal by July. Summer breeding occurred in parts of the Punjab and Rajputana, but it was reported that in Rajputana large numbers of egg masses were destroyed by excessive soil moisture due to heavy rainfall. Autumn swarms were comparatively few. A few flights reached Gwalior and Kathiawar, and a fair number were reported from Sind and Baluchistan in autumn.

YEAR 1908

A. WEATHER NOTES 1908

I.—*Winter-Spring Rainfall* 1907-1908: (*Data in inches*)

1097-1098	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Iran:						
Jask	..	0·69	0·23	..	0·06	..
Arabia:						
Muscat	0·18	0·14	0·22	..	0·39	0·13
Baluchistan:						
Quetta	..	0·18	1·57	0·03	1·22	1·93
Nushki	..	0·02	2·26	..	1·61	1·21
Sind:						
Karachi	..	..	1·03	..	..	..
Punjab:						
Lahore	..	..	1·61	..	0·04	0·63

Winter-spring rainfall was more or less a failure in Persia, Oman and India.

II. *Monsoon Rainfall* 1908: (*Data in inches*)

1908	May	Jun.	Jul.	Aug.	Sept.
Sind :					
Karachi	..	..	5·88	0·36	..
Mithi	..	..	14·07	9·79	0·50
Chachro	..	..	18·30	4·90	..
Rajputana :					
Barmer	..	2·18	12·30	10·76	0·88
Jodhpur	..	0·30	12·60	12·32	10·10
Jaisalmer	1·07	0·49	4·14	8·01	1·92
Bikaner	0·21	0·50	7·30	6·57	2·51
Punjab					
Lahore	0·06	0·96	6·70	17·47	1·54
Sirsa	0·62	1·52	9·69	7·22	0·12

Monsoon rainfall was heavy in July and August, and there was some precipitation even in September in parts of the desert.

B. Locust Data 1908

I. *Winter* 1907-1908. No records. Apparently there was no over-wintering.

II. *Spring* 1908.—*The Punjab*. In March some locusts are reported to have laid eggs in *Lyallpur* in one Zail.

III. *Summer* 1908.—*Cutch State*. Towards the end of August, locusts appeared in parts of Rapar taluka.

IV. *Autumn* 1908.—*Sind*. During week ending 10th November, locusts were reported from Diplo taluka (Thar-Parkar district) causing slight damage to standing crops. On 3rd November, locusts appeared in Jati taluka (Karachi district) and migrated towards the sea after 3 days' stay, and about the same time they also visited Sujawal and Karachi talukas.

Summary of Events in 1908

(1) Winter-spring rainfall in winter rain areas of East Arabia, Iran and Baluchistan was more or less defective. Possibly light *solitaria* breeding might have occurred.

(2) There is no indication of summer flights from the west.

(3) Monsoon rainfall was very heavy all over the desert areas during July and August and there was a fair amount in September also. A fair amount of 'gregaria' breeding had apparently taken place in the southern parts of the desert, since locusts appeared at the end of August at Rapar in Cutch, and other swarms were reported from Thar-Parkar and Karachi districts early in November. These evidently represented some of the usual autumn movements.

YEAR 1909

A. Weather Notes 1909

I.—*Winter-Spring Rainfall* 1908-1909: (*Data in inches*)

1908-1909	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Iran :						
Jask	..	0·46	1·18	1·19	0·02	0·31
Arabia :						
Muscat	..	0·18	4·52	..	..	..
Baluchistan :						
Quetta	..	1·40	1·20	2·86	1·13	1·81
Nushki	..	0·62	0·60	1·72	0·77	..
Sind :						
Karachi	..	..	0·85	..	..	..

Winter Rainfall was moderate, through in January considerable rainfall was recorded at Muscat.

II. *Monsoon Rainfall* 1909: (*Data in inches*)

1909	May	June	July	Aug.	Sept.
Sind :					
Karachi	..	..	3·29	0·36	..
Mithi	..	3·47	10·83	3·25	2·44
Chachro	0·16	..	5·21	2·82	1·73
Rajputana :					
Barmer	..	..	9·47	2·54	2·56
Jodhpur	..	1·14	11·35	0·76	8·11
Jaisalmer	..	0·25	5·33	0·70	1·82
Bikaner	..	2·13	7·57	6·67	4·57
Punjab :					
Sirsa	..	1·35	5·72	5·33	6·04

The monsoon of 1909 was again a heavy one. Rains commenced in June. They were heavy in July and somewhat light in August. Considerable rain also fell in September in many parts.

B. Locust Data 1909

I. *Winter* 1909. No records.

II. *Spring* 1909. No records.

III. *Summer* 1909. No records.

IV. *Autumn* 1909. *Punjab*: *October-November*. Reports of damage to crops in Bhakkar taluk of Mianwali district were received.

Bihar. Locusts are said to have appeared at Baharagura Thana of Singbhum district in October-November and caused slight damage to crops.

Summary of Events in 1909

(1) Winter rainfall was fair in amount and it is likely that breeding had taken place in Oman as there was good rainfall in January.

(2) There were no signs of any immigration of locust swarms from the west in summer.

(3) There was heavy monsoon rainfall in the desert. *Solitaria* breeding had presumably occurred.

(4) The occurrence of locusts in Mianwali district is an indication of westward migration in autumn. The report of locusts in Singbhum district in Bihar is possibly an indication of unnoticed eastward movements of locusts.

YEAR 1910

A. Weather Notes 1910

I.—*Winter-Spring Rainfall* 1909-1910: (*Data in inches*)

1909-1910	Nov.	Dec.	Jan.	Feb.	Mar.	April.
Iran :						
Jask	..	4·72	0·42	..	2·60	..
Arabia :						
Muscat	..	2·14	0·96	..	0·44	..
Baluchistan :						
Quetta	..	1·42	1·72	0·42	1·17	0·81
Nushki	..	1·51	1·35	0·02	0·55	0·14
Sind :						
Karachi	..	0·76	0·43	..	..	..

Winter rainfall was fairly satisfactory in Iran, Oman and Baluchistan.

II.—*Monsoon Rainfall* 1910: (*Data in inches*)

1910	May	June	July	Aug.	Sep.
Sind :					
Karachi	..	2·29	8·14	1·73	..
Mithi	..	0·29	8·25	5·85	0·21
Chachro	..	1·26	3·36	2·09	..
Rajputana :					
Barmer	..	2·15	2·52	2·50	..
Jodhpur	..	5·50	0·64	4·73	0·11
Jaisalmer	..	1·16	1·34	3·20	0·52
Bikaner	..	1·31	2·00	8·87	0·63
Punjab :					
Sirsa	..	2·41	1·62	2·44	2·76

Monsoon rainfall was fairly heavy in the desert. Rains began in June and ended early in September.

B. LOCUST DATA 1910

I. *Winter* 1909-1910. No records.

II. *Spring* 1910. No records.

III. *Summer* 1910. No records.

IV. *Autumn* 1910.—*Punjab*. Locust damage to wheat was reported in the first week of December in Bhakkar tahsil (Mianwali district).

Baluchistan.—November. Locusts visited Bhag and Lehri niabats of Kachhi and damaged crops.

Summary of Events in 1910

(1) Winter-spring rainfall was fairly satisfactory and breeding of solitaries should have been possible in winter in Oman and in spring in south Iran.

(2) No records of summer flights.

(3) Monsoon rainfall was fairly heavy and *solitaria* breeding should have occurred.

(4) Autumn movements are indicated by the occurrence of locusts in Mianwali district in the Punjab in December and in Kachhi area in November.

YEAR 1911

A. WEATHER NOTES 1911

I. *Winter-Spring Rainfall* 1911: (*Data in inches*)

1910-1911	Nov.	Dec.	Jan.	Feb.	Mar.	April
Iran :						
Jask	0·03	2·14	4·46	0·13	0·84	..
Arabia :						
Muscat	..	1·51	2·63	0·10	0·28	..
Baluchistan :						
Pasni	?	?	0·70	..	1·86	..
Quetta	..	?	5·30	0·71	2·85	..
Nushki	..	1·25	4·53	0·15	1·22	..
Mithri	..	1·01	0·85	..	1·94	0·15
Loralai	..	?	2·47	0·55	6·14	2·72
Sind :						
Karachi	..	0·05	0·51	..	4·86	..

II.—*Monsoon Rainfall* 1911: (*Data in inches*)

1911	May	June	July	Aug.	Sep.
Sind :					
Karachi	..	..	..	..	0·0
Mithi	..	0·35	..	0·02	..
Chachro	..	2·33	..	0·17	..
Rajputana :					
Barmer	..	0·20	..	0·29	0·52
Jodhpur	..	1·78	..	0·19	4·12
Desuri	..	0·43	0·29	1·91	6·53
Jaisalmer	..	0·53	..	0·07	0·30
Bikaner	..	0·91	0·44	1·08	0·14
Punjab :					
Sirsa	0·02	1·78	0·27	0·27	..

The monsoon of 1911 was a failure in the desert areas. It began with light falls in June; July was totally dry; in August there were light showers. In September, some fairly heavy falls would appear to have been received in parts of the desert, as for instance in areas adjoining the Aravalli Hills. On the whole, the drought was severe and caused a famine in the desert areas and in Sind.

B. Locust Data 1911

I. *Winter* 1910-1911. No records.

II. *Spring* 1911.—*Kachhi.* The jowar crop was being injured in Bhag Niabat by locusts coming from Mirpur-Nasirabad side in May 1911. Hoppers were, it was stated, "attacking the lower leaves; after getting wings, the adults are now eating the earheads."

III. *Summer* 1911.—*Mekran.* Large swarms were said to have appeared in Dasht ilaqa in Mekran in *June.*

Kachhi. In July, jowar crops in Mauzas Mashkhaf and Brahm Baran were damaged by locusts.

Punjab. Week ending 20*th June* 1911: Locusts damaged cotton and jowar in parts of Shujabad taluk of Multan district.

IV. *Autumn* 1911. No records.

Summary of Events in 1911

(1) The winter-spring rainfall was heavier than usual especially in January and March, in Persia and Arabia as well in Baluchistan.

(2) A fair amount of breeding in spring should have been a possibility in Oman and Iran.

(3) In Kachhi, where good rainfall had occurred and where, moreover, good inundations had presumably been received, breeding apparently took place in March-May and adults were found in May on crops.

(4) In early summer, large numbers of locusts had arrived in Dasht valley in Mekran and damaged crops.

(5) Small flights probably reached the Multan area in the Punjab in mid-June, and were also reported from the Dadhar area in Kachhi in July. There is little doubt that incursions of solitaries had likewise reached the desert areas about this time.

(6) The monsoon was a failure in Sind, Rajputana and the neighbouring areas, but locally heavy showers would appear to have fallen in parts of the desert in September, and isolated breeding might be considered to have been possible.

CHAPTER II

LOCUST CYCLE 1912—1919

SUB-PERIOD 1912—1915

YEAR 1912

A. WEATHER NOTES 1912

I.—*Winter-Spring Rainfall* 1912: (*Data in inches*)

1911-1912	Nov.	Dec.	Jan.	Feb.	Mar.	April
Iran :						
Jask	0·52	0·37	1·72	0·60	..	0·5
Arabia :						
Muscat	0·72	0·25	2·35	0·47	..	3·8
Baluchistan :						
Pasni	0·19	..	1·29	..	..	..
Panjgur	0·01	0·24	1·44	0·04	0·05	0·6
Quetta	1·31	0·56	4·66	0·35	0·38	2·2
Nushki	0·52	0·70	0·42	.	..	..
Sind :						
Karachi	0·26	..	..	.	..	..

There was generally good rainfall in Jask and Muscat in November 1911 and January 1912. There was also a total fall of 3·81″ received in the course of 5 days in April at Muscat, which should have favoured extended spring breeding in Oman

II.—*Monsoon Rainfall* 1912: (*Data in inches*)

1912	May	June	July	Aug.	Sept.
Sind :					
Karachi	..	..	2·62	0·22	..
Mithi	..	0·50	4·80	5·45	..
Chachro	..	1·10	4·44	2·67	..
Rajputana :					
Barmer	1·04	2·45	7·76	2·29	0·14
Jodhpur	0·07	1·65	4·58	6·56	1·85
Jaisalmer	0·12	0·03	2·06	3·09	1·52
Bikaner	0·17	0·90	1·39	2·51	..
Punjab :					
Sirsa	0·12	..	5·93	2·61	1·27

There were good showers about the middle of June and the monsoon extended into Rajputana early in July. Fairly good rainfall occurred during July and August in most parts of the Sind-Rajputana desert. There was a break in the rains between the 12th and 25th August in North West India. The monsoon retreated from the desert area during the first week of September.

B. LOCUST DATA 1912

I. *Winter* 1911-1912. No records.

II. *Spring* 1912. It is recorded that considerable numbers of "red female locusts" were seen during spring at Harnai (Sibi district) in Baluchistan. Presumably these were part of a scattered overwintering locust population.

III. *Summer* 1912. No records. In regard to Rajputana, Rai Sahib Pundit Sham Behari Misra, Revenue Minister, Raj Marwar in a note dated 20th March 1914, classified the year 1912 as one "of initial locust infestation in Marwar". This would indicate that the actual appearance of locust swarms and perhaps of cases of breeding in the monsoon months in parts of Marwar had come to the notice of the authorities of the Jodhpur State.

IV. *Autumn* 1912. Sind. The first record of the appearance of locust swarms in 1912 was in the third week of September in Chachro taluka, Thar-Parkar district. By the end of September swarms had reached other talukas of Thar-Parkar and also parts of Hyderabad. In October, November and December numerous swarms were seen in Karachi, Hyderabad, Sukkur, Thar-Parkar and Nawabshah districts. The direction was in general from east to west and the standing crops and, later on, germinating 'rabi' were damaged. According to Mr. G. S. Henderson (Deputy Director of Agriculture in Sind in 1913) "a great many swarms came across lower Hyderabad and Karachi districts from the Marwar desert in 1912 and did much damage".

Western India States. In October, slight damage to crops was reported from several villages in Palanpur State, and in Cutch State locusts appeared in Bhachau, Abdasa and other talukas without doing much damage.

Baluchistan.—Kachhi. In September and October, locusts appeared in Bhag, Lehri and Dadhar niabats and did some damage to Kharif crops.

Mekran. In October-December, locusts appeared in several places: at Pasni on 9th October, Sami 25th October, Turbat on 28th October, and Levies Tract and Panjgur (23—25 December).

Summary of Events in 1912

(1) Winter-spring rainfall in Iran and Oman was fairly satisfactory and the good falls at Muscat in April should have been favourable for extended spring breeding.

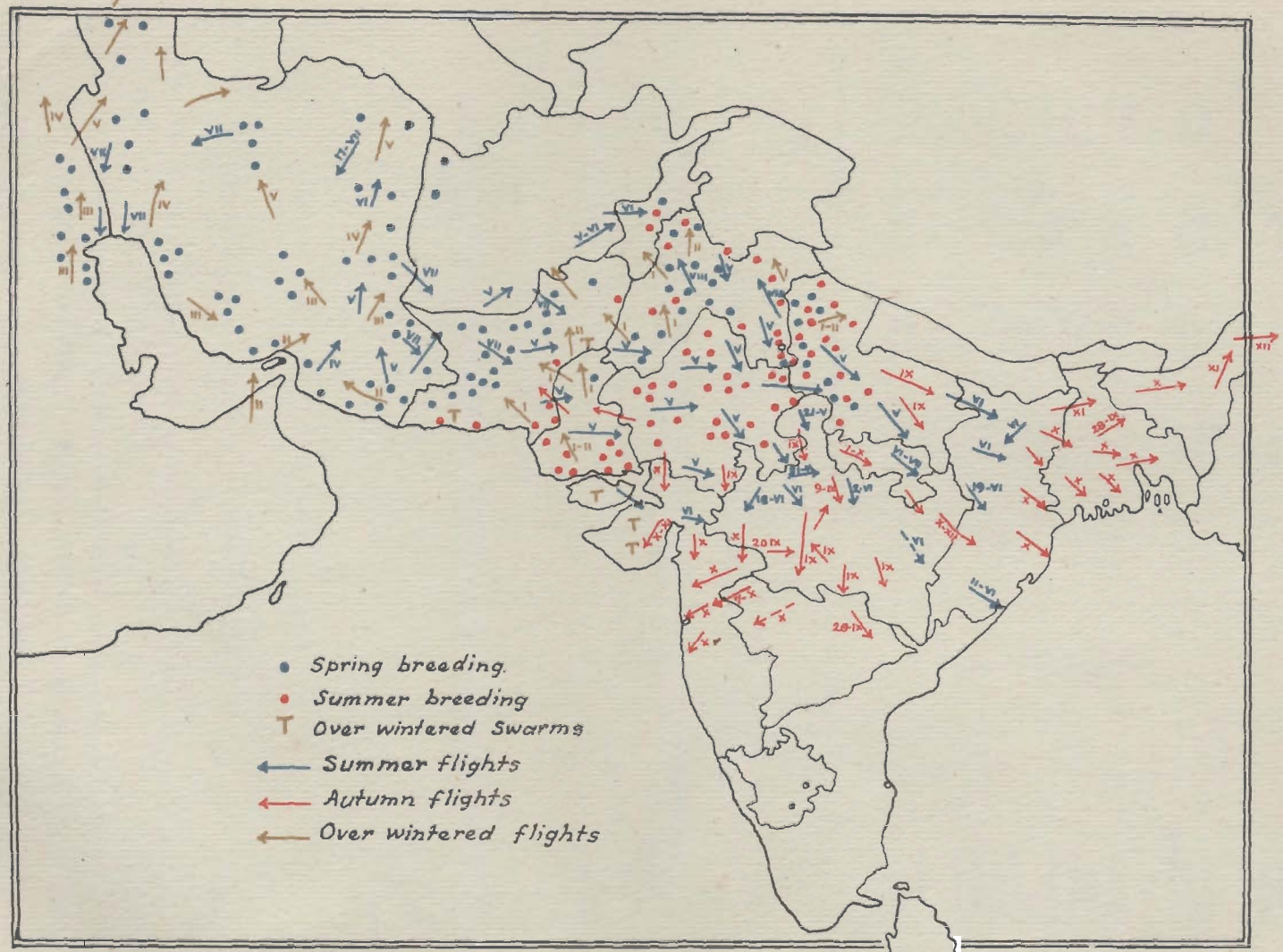
(2) At Harnai, small groups of overwintering locusts were found in spring. Probably similar small concentrations might have been present in coastal Mekran, but there is no indication of spring breeding in British areas.

(3) It is likely that summer flights of solitaries from the west had taken place at the beginning of summer, and had reached the Rajputana desert areas by the beginning of the rains.

(4) Monsoon began in June, when rain fell mostly in South Marwar. In July, there was widespread precipitation which was specially heavy in Thar, southern and eastern Marwar and southern and eastern Bikaner, there being little rain in Jaisalmer and western Bikaner. In August, there was a break in the middle of the month, but the total rainfall was fairly good especially in east Marwar. Only scattered showers fell in September. (*Vide* Pl. 43 Fig. 4).

Breeding had apparently taken place in south and south-east Marwar and possibly in south-east Bikaner during July and August. Owing to the drought in 1911, it may be presumed that the vegetation springing up in June was of a patchy character and had helped in concentrating the breeding into particular confined areas.

In Baluchistan, locusts reached Kachhi in September and flew from Sind across Mekran in the direction of Iran during the months of October, November and December.



LOCUST SITUATION IN 1930 IN THE INDO-IRANIAN AREA

YEAR 1913

A. Weather Notes 1913

I.—*Winter-Spring Rainfall* 1912-13: (*Data in inches*)

1912-13	Nov.	Dec.	Jan.	Feb.	Mar.	April
Iran.						
Jask	0·06	1·87	..	1·50	1·84	
Arabia.						
Muscat	2·20	0·97	..	3·88	0·85	
Baluchistan.						
Pasni	..	1·54	0·23	5·73	..	.
Panjgur	..	0·55	..	1·09	2·42	0·10
Turbat	..	0·90	0·14	2·56	0·18	..
Ormara	..	..	..	4·25	0·30	..
Chaman	0·18	2·43	1·06	1·76	2·05	0·25
Nushki	..	1·07	0·22	2·81	1·46	..
Mithri	..	..	..	0·63	0·49	..
Loralai	..	0·19	0·07	1·55	0·66	2·30
Sind.						
Karachi	..	..	..	1·52	0·32	..

Winter-spring rainfall was apparently satisfactory in South Iran and Oman (especially in February) and also in British Baluchistan.

II.—*Monsoon Rainfall* 1913: (*Data in inches*)

1913	May	June	July	August	Sept.
Sind.—					
Karachi	..	..	12·12	1·42	..
Mithi	..	1·70	13·97	18·18	7·07
Chachro	0·02	0·83	5·37	8·19	10·61
Rajputana.					
Barmer	1·34	3·35	2·78	5·83	1·43
Jodhpur	0·28	1·29	1·64	1·88	1·76
Jaisalmer	..	0·90	0·86	1·88	..
Bap	..	1·21	..	0·93	1·11
Bikaner	0·82	2·03	0·99	0·20	0·70
Nohar	1·47	4·24	5·70	0·90	0·60
Jaipur	1·15	6·96	4·38	0·08	1·29
Ajmer	2·00	3·51	2·69	2·07	1·62
Punjab.					
Rawalpindi	0·75	4·17	4·21	12·62	3·76
Lahore	2·51	1·46	9·99	9·01	0·18
Hissar	1·86	1·82	5·01	0·37	..
Baluchistan.					
Mithri	..	0·40	0·72	2·90	..
Loralai	0·15	0·73	0·94	2·40	0·27
Bela	..	4·08	19·33	3·99	1·60

Monsoon began early; there were fairly wide-spread showers in June; and in July, there was very heavy rainfall in south Sind and Lasbela, Gujarat and Punjab, though little rain fell in most parts of West Rajputana. In August, there was again heavy rainfall in the Thar area of Sind, as well as in Mallani and south Marwar, in the eastern parts of Baluchistan, north Sind and most parts of Punjab. Heavy rainfall continued in the Thar areas of Sind, in Cutch and Gujarat in September.

B. Locust Data 1913

I. *Winter* 1912-13.—(December 1912—February 1913)

Baluchistan. On the 9th January, a flight was reported to have passed over Kharan Kalat in a south-westerly direction, and another to have flown on the 15th January in Chagai in a southerly direction. On the 20th January locusts visited parts of Barkhan tahsil in Loralai district and at about this period swarms were reported to have been moving about Surab-Zehri areas of Jhalawan. On the 2nd February flights passed from Dadhar into Mashkhaf in Kachhi-Bolan area.

Sind. In Sind, swarms were found active in Karachi district in January-February.

These movements would indicate on the analogy of similar movements in Chagai in December 1926 and January 1927, that swarms had passed, in autumn and winter 1912-1913, westwards in the direction of southern Afghanistan and Chagai and that these were moving south into Kharan with the north-easterly winds. In fact, according to Webb Ware, large flights had been seen around Mungochar in Sarawan in winter by Sardar Nauroz Khan, who found the ground still covered in spring by remnants of swarms that had been overcome by cold. The presence of swarms in Barkhan (Loralai) would also indicate that they had probably reached the Dera Ghazi Khan district of the Punjab by December-January.

Some over-wintering locusts were, thus, present in parts of Baluchistan, in parts of Sind and Kachhi and possibly in Dera Ghazi Khan during the winter period.

II. *Spring* 1913.—(March-May 1913)

Baluchistan. The earliest appearance of swarms from the side of Iran was noticed on the Chappar Hills near Dalbandin on the 15th March. Since that time, swarms were being reported from Mekran, Jhalawan and Chagai. In April, locusts were reported to have done considerable damage in Kandahar and Shorawak in Afghanistan.

Eggs were laid in the first week of April at Chadh in Surab niabat of Jhalawan; and towards the middle of the month at various places in the Nushki and Dalbandin ilaquas of Chagai district. Flights passed from Chagai into Shorarud, Sarawan, Loralai, (26th April) and Kachhi (27th April, Bhag). In the south they also passed into Jhalawan (3rd and 29th April), Mekran (Mand, 9th April), and Lasbela (29th April).

During May, numerous swarms were reported from Sarawan at various places (Mastung, Pringabad, Dasht, Pashkaram and Mungochar); from Sibi district (Sibi, Kohlu, Harnai and Nasirabad tahsils); from Loralai district (Barkhan, Musakhel, Sinjawi and Duki tahsils); from Kachhi (Bhag, Lahri and Mashkhaf niabats); and parts of Zhob districts.

Large swarms appeared at Pasni in Mekran on the 19th May and flew away eastwards. During the month oviposition occurred in parts of Sarawan (Mastung and Dasht). and Kachhi (several places in Bhag niabat).

Sind. The first report of the appearance of locusts in Sind was during the first week of May in Kotri taluka of Karachi district. Several flights were reported during May from Sukkur, Larkana, Karachi and Nawabshah districts. These presumably passed on into Jaisalmer and Marwar areas of Rajutana.

Punjab. During the latter half of May, swarms recorded from Lahore, Amritsar and Lyallpur districts.

United Provinces. Locusts were reported as having visited three tahsils of Kanpur district in the last week of May.

III. *Summer* 1913 (June-August 1913)

Spring breeding. Hoppers, that had bred in many places in May in the Bhag and Gandhawa niabats, were still being found in June.

Summer Flights.—Baluchistan. The flights from the west which began in mid-May in Mekran, Jhalawan, Sarawan and Upper Baluchistan passing in the direction of Sind and Punjab, continued during June and July.

During the second week of June, large flights were sighted in Mekran, of which one was found making its way thence into Mungochar valley in Sarawan. Flights were reported damaging *sohru* in Mand and Dasht areas in Mekran. Swarms were observed also in parts of Kachhi and some parts of Sibi district. During July, swarms visited Gwasht in Kharan: the Nushki area in Chagai; Panjgur, Kulanch and Pasni Bunder in Mekran: Mastung, Pringabad and Kalat areas in Sarawan; and various parts of Zhob and Loralai districts. On the 11th July, swarms coming from Chaman direction visited Sariab and Dasht near Quetta and Mastung in Sarawan. In August, locusts visited Bela and Welpat in the second week. Flights were also reported from Quetta-Pishin and Chagai districts and from Kachhi and Sarawan.

Sind. Numerous flights were reported in June, July and August in most parts of Sind.

Punjab. During June and July, swarms were mostly concentrated in the south-eastern districts: Rohtak, Gurgaon, Hissar and Ferozepur, Towards the end of July and during August, they were reported from the central and western areas. Lyallpur, Lahore, Sialkot and Multan, presumably due to the influence of the easterly currents of some Bay depressions. In N. W. Frontier Province, locust swarms were noticed in the first week of July in Bannu district but disappeared soon.

United Provinces. During June, flights of locusts appeared over several districts, the easternmost being Gonda district (82°E. Long.) and by the 5th July they had reached Gorakhpur district (84 E. Long.). in this connection, it may be stated that a study of the daily weather reports for 1913, shows that in May, June and July, easterly winds had been alternating with westerly currents according as depressions developed or not at the head of the Bay of Bengal. During May, strong westerlies prevailed between the 22nd and the 25th, when flights had probably passed on eastwards. This was followed by a long period of strong easterlies up to the 14th June, after which westerlies were

noted till the 18th June, taking swarms up to Gonda. After this strong westerlies prevailed from the 1st to the 4th July, which had presumably carried locusts up to Gorakhpur. During the greater part of July however, only easterly currents were generally prevalent, for which reason the distribution of swarms had evidently shifted to the western parts of the province in the latter half of July.

In fact by the end of July locusts appear to have become confined mostly to Almora and Garhwal.

From the evidence available, it would appear that in 1913 summer migration had reached the easternmost point at Gorakhpur (84°E. Long.) by July.

Summer Breeding 1913.—*Baluchistan.* Breeding would appear to have commenced in Kachhi by the end of August and hoppers emerged in September. In Lasbela, good rains had fallen in July and breeding should be considered likely to have occurred, especially as oviposition took place in the neighbouring areas of Karachi district, but there are no records on the subject.

Sind. Heavy rainfall occurred in July in south Sind including Karachi, and Thar, and in August in Thar-Parkar area. Evidently this was favourable for breeding, but actual records are few. According to John Strip, in an article dated 20th May 1914 on "Locusts in Sind", contributed by him to "The Sind Observer" of Karachi, "locusts came over in 1913, from west and north-west and settled on the Moach plain (near Karachi) where they laid eggs in August. Rainfall was good in Karachi and this brought them". The Deputy Collector, Thar division of Sind reported as follows: "The kharif season of 1913 was a poor one on account of extensive rain. Flights of locusts came from across the Rajputana side and kept moving in the division for some time, but did not do any appreciable damage. They laid eggs at several places and hoppers were destroyed by trenching". According to the Collector of Thar-Parkar, "eggs were laid in Chachro and Khipro talukas. It appears that in September locusts disappeared almost entirely, it being believed that the extraordinary rains in the early part of the month had entirely destroyed them".

Breeding would appear to have occurred in September also in parts of the Upper Sind Frontier district.

Punjab. Egg-laying was reported in June in Rohtak, and Gurgaon, and in July-August also in the districts of Hissar, Ferozepur, Lahore and Lyallpur. Hoppers were found till the middle of September.

Rajputana. The available information for Rajputana is very scrappy. According to the late Rai Bahadur C. S. Misra, who visited Rajputana in October-November 1913, "hoppers hatched out from eggs laid by the earlier swarms were so numerous in some parts of the Jodhpur State that people could only with great difficulty save their reservoirs of drinking water from being polluted by them." According to the season and crop reports from Rajputana, "Grasshoppers" (presumably locust hoppers), had done great damage to crops and grass, and in Ajmer, to standing crops in the first week of August. From a study of the distribution of rainfall in various parts of western Rajputana in July and August, it is evident that it was the southern and south-eastern parganas of Marwar and the south eastern parts of Bikaner, that received comparatively good rainfall, and presumably it was in these parts that breeding occurred.

IV. *Autumn* 1913—(September—November 1913)

Baluchistan.—Breeding. As a result of heavy rainfall in August, oviposition would appear to have taken place in several places (Chattar, Hoti, Bara, Chor, etc.) in Lehri niabat of Kachhi. Hoppers were found in great numbers in October and November in this area. At this time breeding also occurred in Upper Sind Frontier according to Misra, as well as at the foot of the hills near Ghaibi Dero in Larkana district. Probably the submontane areas of these districts, in which wind-blown sand is often found accumulated at the foot of the hills, had all been infested in the wake of good rainfall in August.

Autumn Flights. From September onwards numerous flights were recorded in almost all districts of *Sind,* causing varying degrees of damage to the standing crops. Swarms were reported up to the end of December.

In *Baluchistan,* movements of large swarms were reported from many parts of the country. Towards the middle of October, large swarms reached Khuzdar (Jhalawan) from Lasbela through the Levy Tracts. Flights also occurred in the Loralai and Kachhi areas. On the 12th November, enormous flights of locusts appeared in Hab area and damaged the bajri crops. Subsequently these would appear to have moved from Bela through the Levy Tracts into Khuzdar. Swarms were also reported from Saruna in Jhalawan about this time. In December several swarm movements—generally east to west—would appear to have occurred in Kachhi, Sibi and Jhalawan.

In the *Punjab,* hoppers were being found till the middle of September in Hissar, Rohtak, Ferozepur, Sialkot, Lyallpur, Montgomery, Gujranwala and Muzaffargarh. In December, flights reached as far north-west as Mianwali, and entered the N. W. Frontier Province in the districts of Dera Ismail Khan and Bannu by the last week, causing some damage to crops.

In *Rajputana,* Misra found that swarms had visited Karauli State during September, and that several flights had occurred in Marwar during October. Damage to crops was reported in the season and crop reports of the *Gazette of India* in Marwar and Jaisalmer in the middle of October. Apparently swarms had passed over Alwar, Bhurtpore, Jaipur and Ajmer during October and entered the Gwalior State by middle of October, damaging crops in two parganas. In the south, swarms composed of pink and yellow locusts are reported to have passed over Kalandari in Sirohi State on the 26th September, coming from the direction of Marwar, and causing damage to crops.

In October in the third week, locusts appeared in the Panch Mahals in *Western India States Agency,* in parts of Godhra, Kalol and Jhalol talukas, and in Cutch State (Lakhput taluka). They were also reported from Gujarat from Kaira district, (Matar, Dholka, Mehmudabad and Anand talukas).

During November, swarms were active in Kaira and Rewa Kantha. Reports of locust damage are recorded in the season reports for the second and third weeks of October in the *Hyderabad State* (Deccan) in the districts of Gulbarga, Raichur, Nalgonda, Mahbubnagar and Karimnagar. Apparently these refer mostly to damage by the Deccan grasshopper (*Colemania sphenarioides*).

In the *United Provinces,* swarms were reported from Partabgarh district in the first week of October, and Lucknow in the second week. During November, damage by locusts is said to have occurred in Bijnor, Hardoi, Budaun and Fatehpur districts.

During October-November, flights of locusts were reported in several parts of the Gaya district in *Bihar and Orissa*. A big flight on 13-14th November at Belsund, 13 miles from Sitamarhi, in Muzaffarpur district. Bihar, attacked young mustard and again visited it on the 15th.

Summary of Events in 1913.

(1) Winter rainfall was good especially in February and March, Muscat reporting 3·88 in. in February and 0·85 in. in March; good breeding might be expected to have occurred in the Oman area.

(2) There was satisfactory spring rainfall in Baluchistan. Fairly good breeding was reported from Kharan, Chagai, Sarawan, Kachhi and Jhalawan areas in April, May and June.

(3) Immigration of yellow locusts from Iran commenced in April and reached Kachhi in May-June.

(4) Summer flights from the west began in May and continued in June, July and August. They reached as far east as Gorakhpur in United Provinces.

(5) Heavy rain in the southern parts of Rajputana and in Sind and south-east Punjab followed by fairly good breeding occurred in these areas in July-August, and in Kachhi and north Sind in September.

(6) Autumn flights, in October, occurred (1) moving westwards into Sind, Baluchistan and Punjab, (2) southwards into Cutch and Gujarat and (3) eastwards into Central India, United Provinces and Bihar.

YEAR 1914

A. Weather Notes 1914

I.—*Winter-Spring Rainfall* 1913-1914: (*in inches*)

1913-1914	Nov.	Dec.	Jan.	Feb.	March	April	May
Iran.							
Jask	0·77	0·91	..	3·08	..	..	..
Seistan	0·04	..	..	1·93	0·03	0·07	..
Arabia.							
Muscat	..	0·54	0·12	1·65	0·06	..	..
Bahrein	..	0·54	..	0·49	..	..	..
Koweit	0·21	1·61	0·15	2·26	0·77	..	..
Baluchistan.							
Pasni	0·05	0·91	1·68	5·49	..	..	..
Panjgur	..	0·10	0·07	5·44	0·27	..	..
Turbat	..	1·12	0·75	5·08	0·60	0·20	0·55
Quetta	0·95	0·90	1·70	3·29	1·20	0·97	0·13
Nushki	0·08	0·64	1·12	4·38	0·80	1·23	..
Mithri	..	0·80	0·30	1·40	..	0·20	..
Sind.							
Karachi	..	0·36	..	1·57	..	..	..
N.W.F. Province.							
Peshawar	0·25	0·62	0·41	3·16	1·85	3·22	0·81

There was good rainfall in December 1913 and February 1914, in Iran, Oman and Baluchistan, but there was little rain in the other months.

II.—*Monsoon Rainfall* 1914: (*in inches*)

1914	May	June	July	Aug.	Septr.
Baluchistan.					
Pasni	..	7·32	0·04	..	0·04
Turbat	..	2·59	..	..	1·60
Bela	2·20	3·11	3·21	..	0·12
Sind.					
Karachi	..	4·47	2·12	0·02	0·43
Mithi	0·13	2·78	3·46	0·58	2·47
Chachro	..	0·31	3·05	0·13	3·02
Rajputana.					
Barmer	0·12	1·85	4·72	0·60	1·10
Jodhpur	..	2·50	2·08	4·17	0·81
Jaisalmer	..	1·69	5·63	0·15	2·25
Bikaner	..	2·86	5·54	1·35	2·23
Punjab.					
Hissar	..	1·44	7·32	3·93	4.82
Gurgaon	1·33	0·99	11·11	7·30	10·24
Ferozepur	..	1·80	12·79	1·23	2·25
Lahore	1·47	1·04	11·06	2·20	5·94
Mianwali	1·44	2·03	7·25	2·75	1·39

The monsoon began early: there was fairly considerable rainfall in June in many parts of N. W. India. In south Sind and Mekran, there was heavy rainfall due to the formation of a storm in the Arabian Sea, giving heavy falls of 7·32″ at Pasni and 8·62″ at Ormara, and 4·47″ at Karachi on the coastal areas. In July, there was fairly good rainfall, especially in the Punjab. In August, there was little rain in south Sind, but there was considerable rainfall in September in south Punjab, though there was comparatively little in the desert and in Sind.

B. Locust Data 1914—(*vide* Pl. 52, Fig. 1)

I. *Winter* 1913-1914.—(Dec. 13-Feb. 14)

Baluchistan. Over-wintering swarms were observed in Kachhi and in Sibi (Nasirabad and Sibi tahsils), and in Loralai (Barkhan and Musakhel tahsils) in January. In February, swarms were found moving up the hill valleys of Sibi (Khajak) and Bolan, and as the result of the good rainfall in February, eggs were laid in the vicinity of Kirta leading to the emergence of hoppers in due course. In February, locusts were also found moving into the uplands of Jhalawan at Karkh and Chako from the plains of Sind (24th February) and damaging crops.

Sind. Swarms were reported from Karachi, Hyderabad, Larkana and Thar-Parkar in January-February.

There are no records for the Punjab districts regarding over-wintering swarms.

II. *Spring 1914.*—(March-May 1914)

Baluchistan. In March, locusts were reported from Nasirabad tahsil in the plains and from Babian near Sharigh in the hill valleys in Sibi district.

In April, the first appearance of a swarm from the Persian areas reported in Chagai on the Nushki-Registan Frontier on the 24th April. On the 7th May, swarms were seen in the Dalbandin-Chagai Kalat area moving west to east and one swarm was reported from Barabchah on the Afghan Frontier. On the 11th, egg-laying was observed near Yadgar Chah in Dalbandin area. During May, swarms appeared in Kharan at various places between Hurmagai and Washuk and laid eggs in the "Loras" in these areas. Hoppers were seen at Bakat and various other localities in excessive numbers on 21/V and in fact the greater part of Kharan had been infested.

In Chagai, breeding occurred in the Dalbandin, Nushki and Chagai areas and presumably also to a certain extent in western Sinjrani to the west of Dalbandin. According to the reports of Webb Ware, extensive breeding had occurred at about the same time in the adjoining Persian and Afghan areas: *Persia*: Bam, Sarhad, Mashkhel, Seistan, Nehibandan and Dahanebaghi; *Afghanistan*: Helmand valley and Shelagh area.

Swarms were reported during May also from Kachhi (Mashkhaf and Bhag), Bolan (Kirta) and Jhalawan (Khuzdar), but breeding did not occur.

Apparently there was no breeding during the spring of 1914 in the upland districts of Upper Baluchistan (Sarawan, Quetta-Pishin, Zhob etc.). The yellow swarms arrived late (May) and the months of March and April were comparatively dry in 1914 in these areas.

In the *Punjab*, the earliest swarms were recorded in May in the Talagang tahsil of Attock district and in the N. W. Frontier Province, "young locusts" are recorded as having appeared in one village of Nowshera, Peshawar district, in the Gazette of India in the report for week ending 25th May 1914. It is not clear whether by 'young locusts' 'hoppers' are meant; if so, breeding should have occurred which might have been possible in view of the favourable rainfall.

These locusts had probably reached N. W. Frontier Province *via* Helmand—Arghastan—Kalat-i-Ghilzai route in Afghanistan from Persian Baluchistan and Chagai.

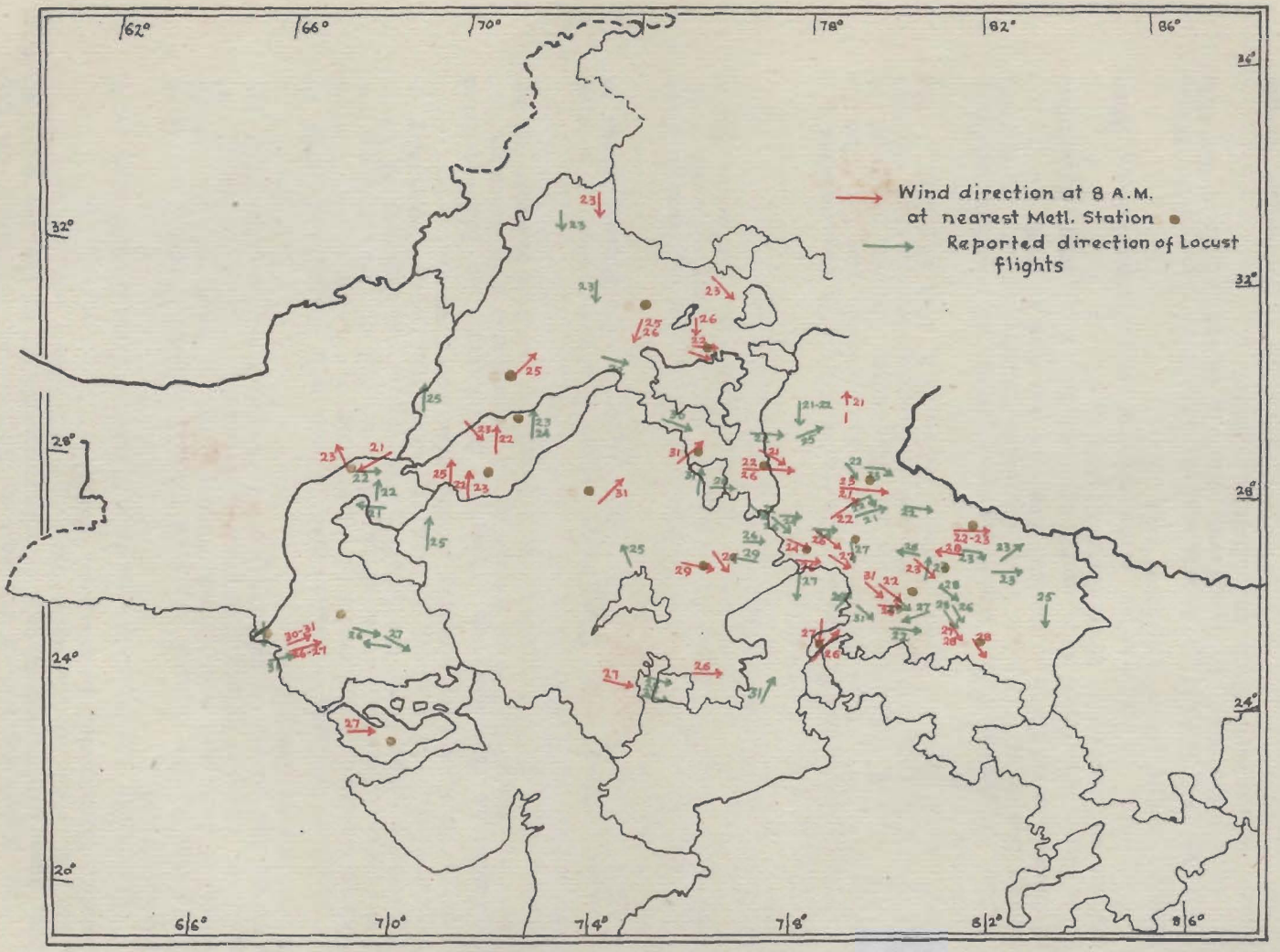
Sind. According to the Sind Official Gazette rabi crops were slightly damaged by *hoppers* in Jati taluka of Karachi in March-April. It is not apparent whether there was any actual locust breeding or only damage by *grasshoppers* is meant.

III. *Summer* 1914 (June-August 1914)

Spring Breeding. Hoppers were still being found by the middle of June in Chagai, though most of the hoppers had become adults by the beginning of the month.

Summer Flights: *Baluchistan.* Flights of locusts began to appear by the first week of June in *Jhalawan* at Khuzdar, Baghwana, Mashkai, Kolachi and Karkh; on the 13th, large swarms are said to have suddenly appeared in the afternoon from the west in Mashkai and to have alighted on the date trees. In *Kachhi,* locusts were reported about the middle of June in the Lehri and Bhag Niabats; in *Mekran,* locusts appeared in the Pasni and Shadi Kaur areas on the 20th June. In July, large swarms appeared in Chagai, Kharan, Jhalawan and Mekran on different dates.

Sind. The first reports of the appearance of western flights in Sind were during the 2nd week of June in Larkana and Nawabshah districts. Swarms also appeared in Upper Sind Frontier district in the 3rd week. The flights continued in July but were, on the whole, comparatively few. There were no swarm movements in August which was dry in the Sind area.



CORRELATION OF WIND DIRECTION WITH DIRECTION OF LOCUST FLIGHTS
PERIOD, 21ST TO 31ST MAY 1930

CHART I

The flights reached as far east as Mahikantha (Pethapur) on the 24th June and Panch Mahals (Godhra and Kalol) in the 4th week of June. In July, locusts were reported from Cutch (Anjar) and Rewa Kantha (Lunavada, Kadana and Sanjeli).

Apparently, the flights passed into *Rajputana* from Sind though there are no records.

In the Punjab, locusts appeared in Hissar district during the third week of June and were found during July in most of the eastern districts, Hissar, Rohtak, Gurgaon and Karnal. It is quite likely that swarms had passed on into the *United Provinces* in June, but there are no records on the subject.

Summer breeding: Baluchistan. There was unusual rainfall in Mekran in June as the result of the activity of a storm in the Arabian Sea, especially on the coastal areas. With the fall of rain, breeding had apparently occurred in the Dasht River valley in Mekran: at Dheli, Kalato, Gabd and Nahang. Owing to defective rainfall especially in August, there was no breeding in the *Sind* desert areas.

Rajputana. Breeding was reported in August in Marwar from Sanchor, Phalodi and Sheo Parganas. It is probable that breeding had occurred also in other parts of Marwar and in parts of Bikaner during August and September.

Western India States. Hoppers are reported to have appeared in large numbers during the week ending 4th August, in the Prantij taluka in Ahmedabad district.

Punjab. Breeding occurred in Hissar, Rohtak, and Gurgaon in June and July and in Ferozepur in August as well. Swarms spread westwards in August into Lyallpur, Multan, Ferozepur, Ludhiana, Montgomery and Dera Ghazi Khan.

IV. *Autumn* 1914: (Sept-Dec. 1914)

Autumn Flights: Baluchistan. In September only two swarms are recorded: one in Zhob district (Killa Saifulla tahsil) and the other in Loralai district (Barkhan tahsil). In November locusts appeared in Kachhi in Bhag niabat on the 7th; and in Mekran, swarms were reported in the Mand area on three different days: 10th, 18th and 21st in the afternoon.

Sind. Numerous flights were reported from all districts of Sind, during September, October and November causing a varying amount of damage to crops. The general direction was east to west.

In December there were only two reports: one from Hyderabad district and the other from Karachi district.

Rajputana. In September some swarms were reported in Sheo pargana coming from Jaisalmer side.

In October, damage by locusts was reported from some of the States of east Rajputana and Jaisalmer, and in November, from Karauli, Kotah, Kishangarh, Tonk and Shahpura States.

Western India States Agency. In the 3rd week of September, locusts appeared in Cutch State (Mundra, Rapar and Kadir talukas). In October swarms were reported from Mahikantha moving from west to east and in November, in Radhanpur, Santalpur, Deodar and Palanpur States. In December, locusts damaged *jowar* and wheat crops in Cutch State (in Mundra, Mandvi, Nakhtarana, Lakhput and Bhuj areas) and in Palanpur (in Deodar area).

Punjab. In September, locusts were reported from Multan and Ferozepur, and in October and November, swarms were found in south-east Punjab—Hissar, Gurgaon and Ferozepur districts.

N. W. F. Province. Locusts were reported in October, causing damage to crops in some parts of the Dera Ismail Khan district.

United Provinces, Bihar and Assam. According to the United Provinces Revenue Administration Report for 1914-15, locusts visited the Province in unusual profusion during the year. Reports of locust damage are, however, recorded in the Gazette of India only from October. During the week ending 3rd October, crop damage was recorded from parts of Agra, Budaun, Mainpuri and Ballia districts. It is evident, therefore, that the swarms, which could have come only from south-east Punjab or east Rajputana—had already reached the easternmost part of the Province *viz.*, Ballia district by the end of September. It is probable that the locust damage reported from Barpeta in Assam during the first week of September had been derived from some very early swarms passing over the United Provinces and Bihar. Daily weather data for the period concerned indicate that westerly winds had prevailed from the 27th August to the 4th September in the United Provinces and in Bihar, which might have carried the early swarms into Bengal and thence into Assam. Southwesterly winds were recorded at Dhubri on the 30th August and the 5th September and these could have taken the swarms into the Barpeta area early in September. In regard to the appearance of swarms in Ballia district during the week ending 4th October, westerly winds are known to have prevailed between the 27th September and 2nd October, which were favourable for the eastward extension of flights up to the Ballia district and beyond into Bihar. The swarms reported damaging paddy in parts of the Sonthal Parganas in Bihar in the third week of October, must have also been part of the autumn flights flying eastwards from the United Provinces.

During October-November, locusts were reported from Jalaun, Jhansi, Banda, Dehra Dun, Kheri, Garhwal and Muttra districts.

In *Central India*, autumn crops were reported to have been damaged by locusts in Gwalior State during the first week of November: evidently the swarms had come either from Rajputana or from southeast Punjab.

Summary of Events in 1914 (Pl. 52, Fig. 1)

(1) There was considerable winter rainfall in December 1913 and February 1914, in Iran, Oman and Baluchistan.

(2) Over-writering was noticeable in parts of Baluchistan and Sind, but not in the Punjab.

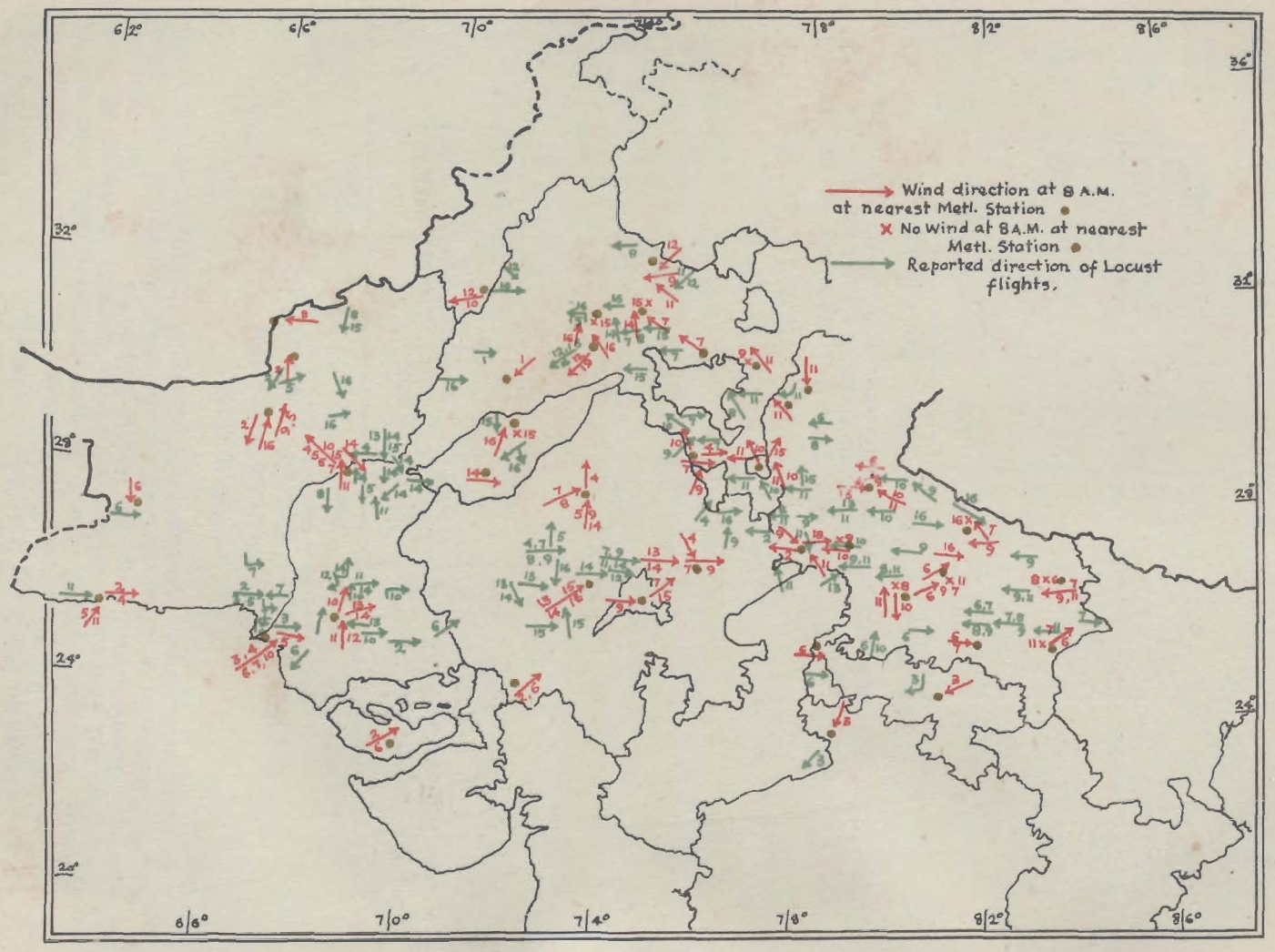
(3) Good breeding probably took place in Iran and Oman; and within Indian limits, early breeding occurred in Bolan valley in February-March.

(4) Movements of yellow locusts began at the end of April in Chagai. Swarms entered Kharan and Chagai in May and breeding occurred in these areas, as also in the adjoining Persian and Afghan areas: Sarhad, Seistan, Helmand valley etc., in May-June.

(5) Summer migration commenced in June and reached Sind and Punjab by middle of June and extended eastwards into United Provinces and Western India States.

(6) Summer breeding occurred in parts of Jodhpur and Bikaner, in Prantij taluka (Gujarat) and in south-east Punjab. Also in parts of Mekran.

(7) Autumn flights commenced in September. In the west, a fairly good number of swarms moved across Sind into Baluchistan in October



CORRELATION OF WIND DIRECTION WITH DIRECTION OF LOCUST FLIGHTS

PERIOD I - 16 JULY 1930.

CHART II

and November. In the Punjab, there were but few swarms moving west, but some reached the N. W. Frontier Province (D. I. Khan) by October.

There was a fairly considerable eastward movement of swarms in autumn. The early flights appear to have moved rapidly over United Provinces and Bihar and reached as far as Barpeta in Assam by September. Others spread over the United Provinces and one reached Sonthal Parganas in Bihar in October. Swarms also spread south from Rajputana into Cutch, Mahikantha, Radhanpur, Palanpur etc. in north Gujrat.

YEAR 1915

A. Weather Notes 1915

I.—*Winter-Spring Rainfall* 1914-1915. (*In inches*)

1914-1915	Nov.	Dec.	Jan.	Feb.	March	April
Iran.						
Jask	0·25	0·11	0·04	..	..	0·18
Seistan	0·69	0·07	0·09	0·03	0·75	0·45
Meshed	1·21	0·62	0·08	0·50	3·68	3·74
Arabia.						
Muscat	1·77	0·88	0·26	0·04	0·10	2·59
Koweit	0·08	0·29	0·23	0·59	0·72	..
Baluchistan.						
Pasni	0·23	..	1·27	2·32	0·49	2·59
Panjgur	0·83	0·06	0·12	0·32	1·87	2.42
Turbat	1·28	0·02	0·25	1·24	0·20	8·33
Quetta	1·91	1·16	0·43	0·45	1·44	1·96
Chaman	2·23	0·44	0·65	0·47	1·77	2·92
Nushki	0·91	0·33	0·96	0·03	0·85	4·23
Pishin	2·92	0·89	0·61	0·56	1·04	2·81
Khuzdar	1·65	..	0·30	..	0·20	0·90
Loralai	1·76	0·38	0·15	..	0·62	4·12
Sind.						
Karachi	..	0·15	..	3·15	0·52	1·32

Winter-Spring rainfall generally defective, especially so on Iranian Coast and Arabia and in Baluchistan in general, except for the month of April when good rain fell in parts of Mekran and Upper Baluchistan.

II.—*Monsoon Rainfall* 1915. (*In inches*)

1915	May	June	July	Aug.	Sept.	Oct.
Sind.						
Karachi	..	..	0·08	0·13	..	0·20
Mithi	..	..	1·07	..	0·95	0·98
Chachro	..	..	0·52	..	0·61	2·21
Rajputana.						
Barmer	..	1·06	0·20	2·53	0·67	0·16
Jodhpur	..	0·45	0·60	1·41	0·40	1·64
Jaisalmer	..	0·81	0·30	..	1·77	..
Bikaner	..	0·26	1·48	0·88	0.05	1·19
Jaipur	0·18	0·52	3·23	4·32	2·41	0·05
Punjab.						
Hissar	0·31	2·11	0·84	0·95	2·36	0·11
Gurgaon	0·59	3·76	4·52	3·84	2·94	0.02
Ferozepur	..	1·35	..	0·57	2·85	1.80
Lahore	..	1·45	0·74	0·87	2·03	0.90
United Provinces.						
Muttra	..	0·68	3·04	2·89	1·62	0.10
Etawah	0·53	0·38	3·55	10·51	2·42	1·51

The monsoon was in great defect in north-west India, especially in the desert areas. In Sind, except for a few light showers in July and September, there was no rain whatever during the monsoon months. In western Rajputana, conditions were not much better. In the Punjab, rainfall was in defect almost all over the Province, but fairly good rainfall occurred in a region enclosed between Gurgaon, Jaipur and Muttra in July and August.

B. LOCUST DATA 1915: (*vide* Pl. 52, Fig. 2)

I. *Winter 1914-15*: (Dec. 1914-Feb. 1915)

Over-wintering locusts were observable in December in parts of the United Provinces and in January in Karachi and Larkana in Sind and in Amritsar in the Punjab. No locusts were noticed in Baluchistan.

II. *Spring 1915*: (March-May 1915)

Baluchistan. The first report of locusts in Baluchistan was that of the passage of a very large flight over Nushki on the 6th March. It came from the direction of Kharan, flying south-west to north-east along with a strong wind and passed on without alighting towards Shorawak and Sarlat Hills. Subsequently, another swarm was sighted on the 12th and several others between the 12th and the 25th including three flights on the 22nd in Chagai district passing west to east. About the third week of March, large flights appeared in Quetta-Pishin from the north; other swarms were reported from Loralai district at Hosri and in Barkhan tahsil from Zhob district, in Hindubagh tahsil and some flights also passed from Chagai into Sarawan and appeared in Kirdagap and Mastung areas.

Towards the end of March, many of the swarms began to couple and lay eggs. The earliest case of oviposition was on the 17th March near Kangi Nawar in Nushki tahsil and subsequently eggs were laid at Ahmedwal and in the Dhak and in many other places. In the last week of March, oviposition would appear to have occurred near Bostan and other places in Quetta-Pishin district and similarly in Sarawan at Ghulaman and other places. In Zhob district, swarms coming from Pishin side laid eggs in Hindubagh tahsil, and later on in Killa Saifulla tahsil; and oviposition occurred at about the same time, also in Loralai district (Hosri, Duki, Rankan etc.), as also in Sibi district at Kach. With the fall of good rain in April, further oviposition would appear to have taken place in Chagai and probably in other areas such as Kharan. Hoppers emerged all over the infested area in April. In Chagai, Quetta, Zhob and Loralai districts, control measures such as collections of eggs and destruction of hoppers by trenching were undertaken as far as possible during April and May.

In Chagai district, hoppers were said to have been spread over the whole country from Sohtagan to Dalbandin, Barabchah, Chagai and Padag being seen everywhere within an area of 200 miles. In the early part of May, hoppers were in the Nushki area in such numbers as to march in large bands into the hilly areas to the east, and many of them were found straying into the railway track between Nushki and Kishinghi, and between Kishinghi and Galangur and causing obstruction to the passage of passenger trains between the 2nd and the 10th May. In Kharan also there was apparently extensive breeding in March-April and it was said that all grass had been eaten up there and crops attacked. By the middle of May, hoppers were becoming winged and the young adults were beginning to fly.

In May-June, 1915, Mr. Cumming, Curator of the McMahon Museum, Quetta found Histerid grubs attacking locust egg-masses at Bostan. Similar grubs collected in May-June 1931 at Kuchlak were reared into beetles of the species *Saprinus ornatus*.

During the early part of May, swarms of the new-fledged locusts were flying north or north-east from Kharan into Chagai and thence into Sarawan, but from about the last week of May and during June, the direction was more or less reversed, flights coming from Afghanistan side and passing south into Persian Baluchistan or into Kharan, apparently due to the development of the north-westerly winds of summar in Seistan-Garmsel areas. Predtechensky also noted a similar change in the flight direction of swarms in the Khorasan areas of Iran, but at a somewhat later date, by the last week of June [Predtechensky 1935].

Movements of pink swarms from the north-west or west were noticeable by the end of May in most parts of Upper Baluchistan: Sarawan, Pishin, Zhob, Loralai, Kachhi and Jhalawan, causing much damage to the Kharif crops (cucurbits and jowar) and to fruit crops and lucerne.

Spring breeding outside Indians Limits. An examination of the available rainfall data for the winter-spring period in Iran and East Arabia would show that rainfall was in great defect in south Iran and in Oman, so that spring breeding could not have occurred in these areas. The prevailing conditions of drought should have caused overwintered swarms present in these areas to migrate much earlier than usual and this would account for the appearance of swarms as early as the first week of March in Kharan and Chagai. As there was a certain amount of precipitation in March followed by heavier rain in April in Chagai and in the uplands, breeding took place in these areas, whereas breeding did not apparently occur in Jhalawan and Mekran. From the records available it is evident that some breeding had taken place in the Registan area of Kandahar and in the Rud-i-Hamun area north of Chagai. There is no information in regard to Kainat and Khorasan in north Persia, but as there was good rain in these areas in March-April, breeding would appear to have been likely.

It may be recalled that under similar conditions of drought in the southern parts of British and Iranian Baluchistan, an early arrival of swarms in Chagai followed by breeding in the upland areas had occurred in the year 1929.

There are no data regarding the occurrence of locusts in *Sind, Punjab* or the *United Provinces* till June.

III.—*Summer 1915*: (June to August 1915)

Summer Flights. As already mentioned the immigration of swarms from the western areas began in *Baluchistan* by the middle of May. Numerous swarms entered Chagai (at Kacha, Merui, Saindak, Padag, Dalbandin etc.) from Afghanistan early in June and passed on into Kharan, and thence into Jhalawan and Mekran towards south-east and east. In Mekran swarms were reported from Panjgur and Kolwa damaging crops and gardens. In Upper Baluchistan numerous flights entered Quetta-Pishin, Zhob and Loralai from Afghanistan. Swarms also appeared in Kachhi in the first week of June from the west.

Such flights continued throughout June, July and August and passed on eastwards or southwards into Punjab, Sind and Rajputana.

In Sind, the first flights of the season were recorded during the first week of June in Karachi, Larkana and Nawabshah districts. Swarms were noticed in almost all the districts of Sind during the months of

June, July and August and caused a varying amount of damage to crops and trees. In July, locusts caused damage to about 500 acres of rice cultivation in Johi taluka (Larkana district). Owing to deficiency in rainfall, there was no breeding in Sind.

Rajputana. Swarms passing through Sind had apparently entered Rajputana, but there is no record in regard to their activities for the year 1915. Due to the prevalence of drought, there was apparently very little breeding except perhaps in parts of Marwar and Bikaner where comparatively better rainfall had occurred.

Western India States. During the last week of June (27-vi-15), swarms appeared from the west in several villages of Lunawada State and passed away eastwards.

Punjab. The earliest report of the presence of locusts in the Punjab is on 11th June in Rojhan area of Dera Ghazi Khan district, the flight direction being east to west (and in this connection it may be stated that the daily weather chart for 11th June shows that easterly winds prevailed in north and central Punjab on the 11th). In June and July they were reported from Multan, Rohtak, Montgomery, Gurgaon, Hoshiarpur and Simla. In August, swarms were reported from Rohtak, Gurgaon, Ferozepur, Hissar, Ambala, Amritsar, Mianwali, Montgomery and Ludhiana.

Breeding occurred only in Gurgaon and Rohtak.

N. W. Frontier Province. During the first week of June, slight damage to extra spring crops was caused by locusts in the Dera Ismail Khan district.

United Provinces. In the first week of June, serious locust damage to sugarcane was reported in Chunar tahsil of Mirzapur district (83°E. Long.). There are no further records for June, but in July, swarms were reported from several districts; Dehra Dun, Nainital, Meerut, Agra, Muttra, Aligarh, Cawnpore, Lucknow, Fyzabad, Basti, etc. (Basti being 83°E. Long). By middle of August, swarms were found restricted to the north-western districts, the easternmost district being Pilibhit (80°E. Long.) and by the end of August, they were reported only from Dehra Dun and Almora districts. In seeking for an explanation of these rather anomalous locust movements, an examination of the wind movements charted out for this period in the Indian Daily Weather Reports for 1915, has given valuable correlation. Strong westerly winds prevailed from the 16th May to the 1st June in the southern districts of the United Provinces and had presumably carried locusts eastwards up to Mirzapur by the beginning of June. From the 2nd June, the Bay Current exerted its influence and easterly winds were prevalent during the whole of June. From the 7th to the 11th July, strong westerlies again prevailed and should have brought the swarms as far east as Basti. After the 12th, however, easterlies again set in, and evidently the swarms were shifted westwards during August by these easterly wind currents. Between the 7th and 14th July, during the period of activity of the westerly winds, swarms are said to have passed over Dehra Dun northwards to Rajapur and thence over the Mussouri ridge (6,000 ft. high). During July-August swarms were similarly active also in Garhwal district.

Central Provinces. During the week ending 29th June, locusts were reported in great numbers from the Narsinghpur district and in the first week of July, they were found in Mandla district, and also in Amraoti district in Berar. During the last week of July, locusts visited Saugor

district. It may be noted in this connection that between the 20th and the 27th June, northerly or north-westerly winds prevailed in the regions of Central India and Central Provinces under the influence of a storm passing north-westwards from the Orissa coast and in July, north-westerly winds were prevalent at Amraoti during the first week, and strong south-westerlies during the last week at Saugor.

Bengal and Assam. On the 8th July, locust swarms were seen coming from the southwest with a strong south-west wind in a tea Estate in the Terai area; and also in an estate in south-east Jalpaiguri. The swarms were found gradually advancing northward into the hills, reaching Kurseong (4,860 ft.) on the 11th and Ghoom (7,408 ft.) Darjiling (7,002 ft.) on the 18th [Andrewes, 1916]. According to the Season and Crop Report of the Gazette of India for week ending 10th July, there was damage to paddy by locusts in Khasi and Jaintia Hills in Assam. In the Assam area, south-westerly winds prevailed at Dhubri, Dinajpur and Gauhati on the 8th and 10th July and should have helped the entrance of swarms into Assam. At about the same period, the south-westerlies prevalent in north Bengal might have carried the flights up into Jalpaiguri and Darjeeling areas.

Reviewing all the data given above in regard to the movements of locust swarms, it is seen that vast numbers of locusts bred in Upper Baluchistan and in parts of the interior of Persia migrated east into Sind and the Punjab, during the latter part of May and early June and reached as far east as Mirzapur district by the beginning of June and the Central Provinces during the last week; and some of the swarms from Central Provinces continued their migration and reached the Jalpaiguri and Darjeeling districts by the middle of July and the Khasi and Jaintia Hills at about the same time. In the south they reached Lunawada State also by the end of June. Such a rapid advance of swarms is presumed to have been due to the unusual dry weather that prevailed during June and July in many parts of N. W. India, which in addition, also contributed to make the conditions very unfavourable for breeding in these areas.

IV. *Autumn 1915* (Sept.—Nov. 1915)

Summer Breeding. Except in Gurgaon and Rohtak, there was little breeding anywhere. There were, therefore, few swarms of the new generation to be found in any part of India in autumn. Specimens of locust hoppers were, however, received by the Imperial Entomologist, Pusa from the Collector of Budaun (U.P.) on 23rd September 1915.

Autumn Flights: Baluchistan. In September, a few swarms were found active in Loralai district (Duki, Sinjawi and Bori tahsils) attacking crops. These probably were the last contingents of the summer flights hailing from the western breeding areas. The flying locusts reported in September from the Killa Saifulla and Fort Sandeman tahsils of the Zhob district probably also belonged to the same category. In Kachhi, a swarm visited Belpat in Bhag area on the 18th September. It came from the west and flew eastwards. Another swarm appeared on the 16th September in Bhag area, which apparently came from south-east from Sind. There are no other reports of swarms movements during the rest of the year.

Sind. In September, a small number of swarms appeared in Sukkur (Shikarpur taluka) and Upper Sind Frontier (Thul, Jacobabad and

Kandhkot talukas) causing some damage to crops. In October, a few appeared in Nawabshah (Sakrand), Upper Sind Frontier and Karachi (Kotri). No flights in November and December.

Punjab. Some locusts were found in Rohtak and Shahpur districts in September and a few in Muzaffargarh district in one Zail.

United Provinces. The writer is indebted to Mr. O. C. Caroe (now Sir Olaf Caroe) Revenue Commissioner, Quetta in 1938, for information given by him in respect of masses of dead locusts found by him on the ice in the Pindari Glacier in Garhwal at a height of 13,000 ft. on the Himalayas in September 1915. Large swarms are known to have been active in July and August in the Dehra Dun, Almora and Garhwal districts and it is probable that some of these had been carried up along the hill valleys by strong monsoon gales till they met their doom on the ice-bound sides of the higher ranges. It is perhaps this fact that had led "KIM" of "Statesman" fame facetiously to comment on the propensity of locust swarms to commit mass suicide on the snows of the Himalayas.

From the data recorded in the season reports of the United Provinces Gazette of 1915, it is seen that locust swarms appeared once again in the eastern districts of the provinces during September. By the third week of the month locusts had appeared as far east as Cawnpore and Ballia districts, presumably on account of the development of westerly winds. There is, however, no further information about locusts after this week.

Summary of Events in 1915: (*Vide* Pl. 52, Fig. 2)

(1) Winter rainfall was generally defective in Iran and Oman, and in British Baluchistan, but fairly good rain was received in April in Upper Baluchistan and Mekran.

(2) Over-wintering swarms were not seen except for a few in Sind, United Provinces and Punjab (Amritsar).

(3) Owing to the drought prevailing in Oman and south Iran, numerous flights appeared in Chagai in the first week of March, nearly a month earlier than usual; oviposition and fairly considerable breeding occurred in Kharan and Chagai and later on to a certain extent in Quetta-Pishin, Sarawan, Zhob and Loralai districts.

(4) Western migrants entered India in June and were reported from the Central Provinces by end of June and had reached as far as Khasi and Jaintia Hills in Assam and the Darjiling district in Bengal by middle of July. The rapidity of the advance of the swarms was probably due to the unusual drought resulting from defective rainfall in June-July in Punjab and United Provinces.

(5) There was very little breeding in summer except in Rohtak and Gurgaon in Punjab and perhaps in Jodhpur, Bikaner and Jaipur in Rajputana.

(6) There were very few autumn flights except in United Provinces and to a slight extent in Sind during September.

CHAPTER III

SUB-PERIOD 1916—1919

YEAR 1916

A. WEATHER NOTES 1916

I—*Winter-Spring Rainfall* 1915-1916 (*Rainfall in inches*)

1915-1916	Nov.	Dec.	Jan.	Feb.	Mar.	April
Iran:						
Jask	..	..	2·60	0·26	0·73	2·32
Meshed	..	0·35	1·34	1·03	2·87	1·46
Arabia:						
Muscat	..	0·27	3·85	1·17	0·20	3·87
Baluchistan:						
Pasni	..	1·10	2·06	0·93	..	1·11
Panjgur	..	1·76	2·58	1·47	..	0·25
Turbat	..	0·76	4·36	0·98	..	0·34
Quetta	..	..	2·65	1·53	0·28	1·99
Nushki	..	..	1·89	1·65	0·47	0·29
Sind:						
Karachi	..	..	0·01	..	..	..

Winter rainfall late, with good falls in January and again in April in Iran and Oman. In Baluchistan good rainfall only in January; only light falls in other months.

II—*Monsoon Rainfall* 1916 (*in inches*)

1916	May	June	July	Aug.	Sep.
Baluchistan:					
Nushki	..	..	..	1·33	...
Sind:					
Karachi	..	0·41	7·88	12·12	1·54
Mithi	..	1·75	2·29	7·24	1·63
Chachro	..	1·85	2·50	8·25	8·08
Rajputana:					
Barmer	0·45	..	2·90	4·82	1·72
Jodhpur	2·27	0·59	1·24	0·24	12·44
Jaisalmer	0·15	0·58	4·51	3·92	2·39
Bikaner	2·84	2·17	6·09	4·93	2·65
Jaipur	0·18	2·17	3·85	12·04	3·79
Punjab:					
Hissar	2·47	1·05	1·73	12·08	2·75
Gurgaon	0·08	1·42	7·68	8·82	6·56
United Provinces:					
Etawah	0·04	3·04	10·53	10·60	10·75
Muttra	..	1·38	4·38	8·45	4·03

Monsoon began at the end June; less than normal rain in many places in July, very heavy rain in most places in August, fairly considerable rainfall in September in many places. On the whole a good monsoon.

B. Locust Data 1916

I. *Winter 1916*: No records.

II. *Spring 1916*: No records.

III. *Summer 1916*: (June to August 1916)

Although there were no concentrations of over-wintering locusts in Baluchistan, Sind or Punjab during the winter and spring months, locust swarms began to appear in these areas by June. In this connection a telegram from the British Council at Ispahan to Col. Wilson, Basra to the effect "locusts responsible for famine in Fars" would show that there was heavy breeding in Iran interior in late spring.

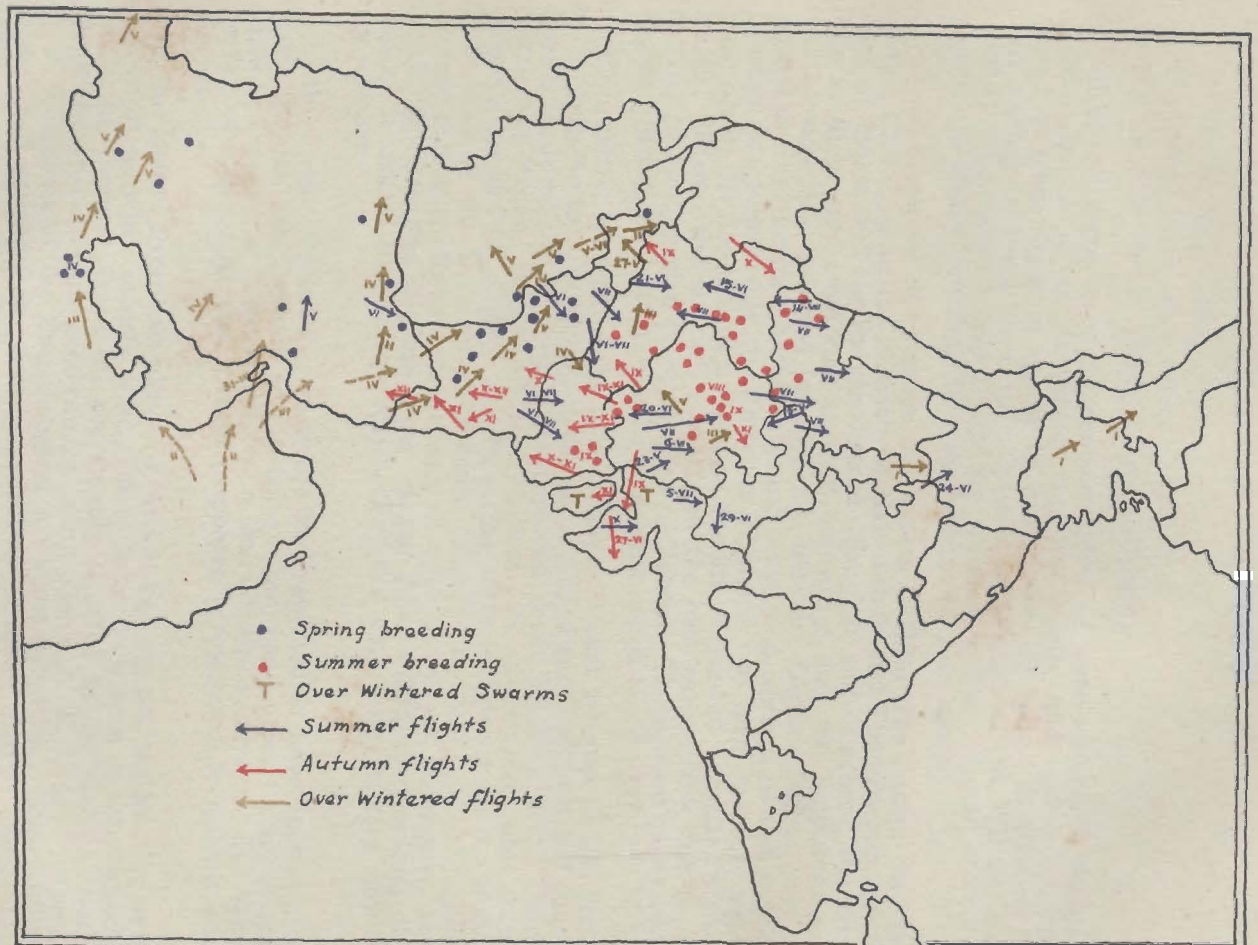
The first report of entrance of swarms in Sind was during the week ending 20th June in the districts of Nawabshah and Thar-Parkar. In the case of flights in Thar-Parkar district (Sanghar and Chachro), the direction of flight was from east to west indicating that the Rajputana area had already been infested prior to this period. Further flights were reported during the months of July and August in almost all the districts of Sind and presumably the direction of flights was from west to east in most cases. In the case of a flight on the 8th August at Sanghar in Thar-Parkar district, the swarms came from the east presumably due to the activity of a depression from the Bay of Bengal. There were heavy rains in Sind during the last two weeks of August, when there were few flights.

The earliest records of the appearance of locust swarms in the *States of Western India*, also pertain to the same period *viz.*, the third and fourth weeks of June, when they were reported from Kaira district, Cutch, Kathiawar, Panch Mahals and Rewa Kantha (the easternmost point reached being about 74 E. Long). The following statement occurs in the Statistical Atlas of the Bombay Presidency [1924]: "In June and July 1916, swarms of the north-west locust spread over parts of Viramgam and Prantij talukas and Modasa Peta of the Ahmedabad district and the Nadiad taluka of the Kaira district; they did not, however, stop and do any damage."

In the *Punjab*, locust swarms were first reported to have appeared in Hissar, Rohtak and Ambala at the end of June, and at that time strong winds are said to have prevailed and a lack of rain was being felt. With the fall of rain in August breeding apparently occurred in Rohtak and Gurgaon.

In the *United Provinces* also, the earliest reports pertain to the last week of June, when locusts were said to have been seen in ten districts and in the Rampur State, all presumably situated in the north-western part of the province, the easternmost being Kheri (81 E. Long). According to the report of the Entomological Assistant dated 14th August 1916, "locusts had appeared in Auraiya tahsil of Etawah district about the middle of June, and had subsequently laid eggs. Hoppers emerged during July-August and caused much damage and inconvenience to the local inhabitants." During July, locusts visited several districts including Etawah, Muttra, Jhansi and the Tehri State.

In *Baluchistan*, locusts are said to have appeared at Kacha outpost in western Chagai on the 5th July, and laid eggs in the Kacha garden.



LOCUST SITUATION IN 1931 IN INDO-IRANIAN AREA

On the 13th July, swarms were reported from Hindubagh and Killa Saifulla tahsils in Zhob district, on the 16th July, from Sinjawi, Bori and Duki tahsils of Loralai district, and between the 14th and 18th July from the Dadhar and Lehri niabats in Kachhi, where they arrived in general either from the north or the north-west and flew eastwards.

From the premises available, it may, perhaps, be permissible to presume that locusts had bred in the spring months in Oman and Iran, had entered south Baluchistan during June and had rapidly passed across Mekran into Sind and thence into Rajputana, Cutch and the western India States as far as Kathiawar and Panch-mahals. From Rajputana, swarms probably reached the south-eastern districts of the Punjab and thence passed into the United Provinces as far as Kheri district. Breeding is known to have occurred in Etawah district and it is not unlikely that it had taken place in some other districts too.

Summer Breeding. In the Punjab, oviposition was reported from Gurgaon and Rohtak and from Etawah in United Provinces. There are no records of breeding in either Sind or Rajputana. Since there was good rainfall in August and September in the Thar area of Sind and in the Rajputana desert. It may be presumed that breeding had occurred in many of these areas, though on account of the heavy falls received in parts of the desert, breeding might have been adversely affected. The fairly good number of swarms reported in Sind during the autumn months had, doubtless, had their origin in the Sind-Rajputana desert areas.

IV. *Autumn* 1916: (September—November 1916).

There are no records for the Punjab and the United Provinces.

Sind. The first flights were reported at the end of September from Thar-Parkar, Hyderabad and Nawabshah districts. During October swarms were appearing in most parts of Sind causing slight damage to crops and trees and apparently passing westwards into Baluchistan by stages, but in November and December, the swarms would appear to have diminished greatly in numbers.

Baluchistan. There are only two records: One is from Kachhi where damage to *jamba* crops was reported from Bhag niabat in October; and the other is about the appearance of locusts at Jiwani Bunder on the Mekran coast on the 27th October.

Western India States. It is mentioned in the *Statistical Atlas* of the Bombay Presidency [1924], that "small swarms of a second brood (bred in Rajputana) appeared in October in north Gujarat, but did no injury to the crops".

Reports of "locusts" attacking crops in parts of Raichur district of Hyderabad during the second and third week of October are recorded in the season reports of the Gazette of India for 1916, but presumably refer to damage by the Deccan Grasshopper.

Summary of Events in 1916

(1) Winter and spring rainfall in southern Iran and in Oman would appear to have been favourable for spring breeding.

(2) There were no overwintering locusts in the Indian areas during winter and spring.

(3) Swarms from the western areas began to appear by the middle of June in Sind, Western India States and presumably also in Rajputana.

Subsequently they were reported also in south-east Punjab and north-west United Provinces (up to Kheri district in the east).

(4) Summer breeding occurred in Gurgaon and Rohtak in the Punjab and Etawah in United Provinces, and presumably also in parts of Rajputana. Heavy rains in August-September were possibly prejudicial to breeding in parts of the desert.

(5) Autumn flights were limited to movements in Sind and Baluchistan during October-November.

YEAR 1917

A. Weather Notes 1917

I—*Winter-Spring Rainfall* 1916-1917 (*in inches*)

1916-1917	Nov.	Dec.	Jan.	Feb.	Mar.	April
Iran :						
Jask	..	0·62	8 05	0·56	..	..
Arabia :						
Muscat	..	..	8·38	0 73	..	0·07
Baluchistan :						
Pasni	..	0·07	8·38	0 42	0·65	..
Panjgur	..	..	1·56	..	1·99	0·18
Quetta	..	0·08	2·14	0 08	2·03	0·10
Nushki	..	0·18	1·44	0·30	0·87	..
Barkhan	..	..	0·99	..	0 91	1·09
Sind :						
Karachi	..	..	0·18	..	0·40	0·28

A ftir amount of rainfall in January in Iran, Oman and Baluchistan; some rainfall in March in Baluchistan; otherwise rainfall defective every where.

II—*Monsoon Rainfall* 1917 (*in inches*)

1917	May	June	July	Aug.	Sept.	Oct.
Baluchistan:						
Barkhan	0·25	0·31	8·14	7·21	9·64	..
Sind :						
Karachi	..	..	..	2·08	2·31	..
Mithi	9·27	1·92	3·92	16·41	9 66	2·66
Chachro	1·16	1·83	0·63	7·55	7·75	2·82
Rajputana:						
Barmer	1·24	1 64	7·01	6 21	4·20	2·70
Jodhpur	4·15	4·75	5·78	14·20	5 74	6·02
Jaisalmer	1·73	2·17	0·60	8·44	7·73	0.62
Bikaner	4·52	0·85	0·79	9·85	7·74	4·35
Jaipur	2·20	3·04	13·09	14·85	14·37	2·82
Punjab :						
Hissar	0 63	1·95	1·74	4·49	18·00	6·62
Gurgaon	1·39	1·81	10·72	8 41	10·40	2·68

There were good pre-monsoon rains in May, and a fair amount of rain in June. Monsoon commenced in earnest in July, but there was little rainfall in Chachro, Jaisalmer, Bikaner and Hissar; there were heavy rains in August and September. Good showers occurred in October also.

B. Locust Data 1917

I. *Winter* 1916-1917: No data available.

II. *Spring* 1917: (*March-May* 1917).

Baluchistan. On the 5th March, locusts were observed near Kacha Thana in Chagai, which were probably remnants of some passing swarm. On the 18th and the 19th April, flights passed over Kacha northwards towards the Helmand. Again towards the end of April, swarms passed over Kacha northwards in the direction of Rod (River Helmand).

In *Jhalawan,* locusts appeared in Gidar *ilaqua* at the end of March and fresh swarms were noticed on the 3rd April near Gidar, where they were reported to have *laid eggs.* In the first week of May, locusts came from Kharan in large numbers and passed over Gidar towards the north. By the middle of May they were reported to have passed away eastwards.

In mid-May swarms appeared in the Bhag niabat of Kachhi and after causing damage to crops passed northeastwards into Lahri niabat. Locusts were also reported from Zhob district towards the end of May, and from Mall in Sibi. A swarm was said to have appeared at Ranrkhan in Barkhan tahsil of Loralai about middle of May and laid eggs, and then disappeared in the direction of Dera Ghazi Khan district of the Punjab.

Sind. The first reports of swarms in Sind were received during the second week of May, when they appeared at Mirokhan in Larkana and at Shadadkot in Upper Sind Frontier. There were further reports during the second half of May from Kakar, Labdaria, Dadu and Mirokhan in Larkana. There were no records of flights in June and July.

III. *Summer* 1917: (June—August 1917)

Baluchistan. In June swarms appeared in Kachhi (Bagh and Lahri niabats) between the 8th and the 19th June; in Zhob district a large flight appeared at Dhanasar on the 12th June and left in the direction of Lowara; and in the Loralai district, a swarm of locusts appeared on the 19th and the 20th June in the Barkhan and Sinjawi tahsils. In July, damage to tobacco and rice crops was reported from Mashkai niabat in Jhalawan and to summer crops from Bhag in Kachhi. In July *hoppers* were found in Rankhan area in Loralai district, being the offspring of eggs laid in May by a passing swarm. In August, there were heavy flights all over Baluchistan. On the 4th there were reports from Mekran on the 5th and the 6th from Jhalawan and on the 10th from the Gandhawa niabat of Kachhi, where flights passed from north to south. On the 16th a swarm of flying locusts visited Mahal Kasimzai of Pishin tahsil and flew to Sarwisht. Another swarm appeared on the same date in Nauhissar from Mehtarzai of Pishin tahsil and flew away towards Samungli and Khezi and disappeared in the direction of Chiltan Range opposite Quetta. On the 18th and the 19th, swarms appeared in Gandhawa niabat in Kachhi and on the 21st in Lahri niabat where all the millet was destroyed. In the third week of August, flying locusts were seen in Duki, Bori and Barkhan tahsils of Loralai district.

In *Sind,* there were no records of flights in June and July, but in August, there was a fresh wave of migration from the west which

appeared in the Upper Sind Frontier, Sukkur, Larkana, Thar-Parkar and Nawabshah districts.

In the *Punjab*, the earliest recorded occurrence of flights is in *June* in the district of Hissar, Gurgaon and Lahore. In *July* there are reports from Hissar and Rohtak. However, there would seem to be strong grounds to think that in May, swarms from Barkhan had passed into Dera Ghazi Khan district.

For *Rajputana*, there are no records, but there is little doubt that all the swarms from Sind had passed into Rajputana and that the flights reported from Hissar and Gurgaon in June had been derived thence.

From the above data, it may be surmised that there were over-wintering locusts in Oman and south Iran and that winter-breeding had probably been induced in these areas after the good rainfall of January. Swarms of the over-wintered generation began to fly north in February-March and reached Chagai (Kacha area), Kharan and Jhalawan in March-April and laid eggs in Gidar (April). The spring brood produced in Iran and Oman began to migrate into Baluchistan by May and reached Sind and Rajputana by the middle of the month and the Punjab by the beginning of June. Some of the swarms of this batch laid eggs in Barkhan in May. In August, there was a third wave of migration of locusts bred probably higher up in Iran in late spring, which passed over various parts of Baluchistan into Sind and possibly Rajputana.

Summer Breeding. The hoppers found in Barkhan area in Loralai in June-July should be deemed to be a case of late spring breeding. The only case of a summer brood is the one recorded in Hissar (Punjab) where eggs were said to have been laid in June. Since, however, there was heavy rainfall in the desert areas from July to October, it is quite likely that breeding had occurred in parts of the desert, though on account of the growth of heavy vegetation, there should have been a likelihood of a reversion to the solitary phase in most cases. The excessive rainfall might also have affected eggs laid in soil and curbed gregarious breeding a great deal.

IV. *Autumn* 1917: (September—November 1917)

There are few data in regard to autumn. In September, locusts are reported to have appeared in Cutch in Lakhput area during the second week.

In November, flights of young locusts are recorded in Luni taluk of Loralai district, and again in December, damage to sprouting wheat is reported from Rakhni and Ranrkhan in Barkhan tahsil.

In *Sind*, lucerne is said to have been slightly damaged by locusts in Karachi taluka.

Summary of Events 1917

(1) Winter rainfall in Iran and Oman was generally in defect except for good falls in January. In Baluchistan, there was some rainfall in March in addition.

(2) Breeding had probably occurred in Iran and Oman in February-March. Over-wintered locusts migrated north into Chagai and north-east into Jhalawan in March-April and laid a few eggs at Gidar in Jhalawan.

(3) Flights of locusts bred in spring in Oman and Iran appeared in Baluchistan and Sind in May and Punjab in June. There was a further wide-spread wave of migration in August in Baluchistan and Sind.

(4) Monsoon was heavy and prolonged in the desert and the Punjab, but, with the exception of a single case of egg laying in Hissar, there are no records of breeding. Breeding in the desert should have been likely, but probably on account of the heavy growth of vegetation there might have been a reversion to the solitary phase on large scale and heavy rainfall might have curbed gregarious breeding a great deal.

(5) A few autumn flights are on record in Cutch (September), in Sind Baluchistan in November and December.

YEAR 1918

A. Weather Notes 1918

I—*Winter-Spring Rainfall* 1917-1918 (*in inches*)

1917-1918	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Iran						
Jask	..	2·41	0·05	..	4·77	0·83
Meshed	0·22	0·51	1·83	1·35	4·21	1·67
Ispahan	..	1·48	0·05	0·80	0·72	2·18
Arabia						
Muscat	..	0·96	0·16	..	0·39	0·31
Baluchistan						
Pasni	..	0·47	0·06	..	5·97	0·17
Panjgur	..	0·41	..	..	1·39	0·03
Quetta	..	1·02	0·15	1·79	4·19	0·42
Nushki	..	0·86	0·25	0·43	5·37	0·16
Sind						
Karachi	..	..	..	..	1·33	..

In Jask there were good falls in December and March, but in Muscat rainfall seems to have been largely in defect. In Baluchistan, rainfall was below average except in March, when there was heavy rain.

II—*Monsoon Rainfall* 1918 (*in inches*)

1918	May	June	July	Aug.	Sept.
Sind					
Karachi	..	..	..	..	..
Mithi	..	..	..	1·94	0·25
Chachro	..	..	..	0·59	1·26
Rajputana					
Barmer	..	..	..	0·98	0·15
Jodhpur	0·95	..	..	1·11	..
Jaisalmer	..	..	..	..	..
Bikaner	..	0·13	..	0·74	0·10
Jaipur	..	0·03	0·83	6·16	1·46
Punjab					
Hissar	..	0·46	..	5·77	0·60
Gurgaon	..	1·74	0·47	5·63	..

The monsoon of 1918 would have been an almost complete failure had it not been for the showers received in August and September. In the Punjab and east Rajputana, however, fairly good rainfall occurred in August.

B. Locust Data 1918

I. *Winter* 1917-1918: No records.

II. *Spring* 1918: (March—May 1918)

Baluchistan. In Chagai, a few locusts were found flying north to south in Dhak, at Padag on the 21st May, and near Yadgar Chah, on the 23rd

III. *Summer 1918*: (June—August, 1918)

Baluchistan. In Jhalawan, locusts were said to have appeared in large numbers in Khuzdar niabat and to have been doing damage to kharif crops at the end of June.

During the last week of August, locusts were again reported to have visited Khuzdar ilaqua and damaged the kharif crops.

In Loralai district, "tiddi" is said to have appeared in Barkhan and Musakhel tahsils in August and its young ones to have damaged the crops. The pest referred to is probably a grasshopper—*Caloptenopsis sp.* —known to attack crops in the Loralai district.

IV. *Autumn 1918*: (September—November 1918)

The monsoon of 1918 being a failure in the desert areas, there was evidently no breeding anywhere, except perhaps for some *solitaria* breeding in the few places, where rain had fallen in August.

There are no records of autumn flights.

Summary of Events in 1918

(1) Winter-spring rainfall was defective except for falls in December 1917. and March 1918 in southern Iran and in Oman. In Baluchistan and the Punjab, there was good rainfall in March, 1918.

(2) Spring breeding had probably occurred in Oman and southern Iran, and possibly also in Persian Baluchistan and Seistan.

(3) In May, locusts of a new generation were found flying southward in Chagai from the direction of Afghanistan. At the end of June, locusts were found in large number in the Khuzdar area of Jhalawan and again in the last week of August. These presumably represented the usual summer migration from the west.

(4) The monsoon being a failure, there was apparently no breeding in summer and consequently no autumn flights.

YEAR 1919

A. Weather Notes 1919

I—*Winter-Spring Rainfall 1918-1919 (in inches)*

1918-1919	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Iran.							
Jask .	..	0·53	3·60	1·05	..	..	0·3
Seistan .	..	..	0·71	0·12	..	..	..
Arabia.							
Muscat .	..	1·52	0·85	0·86	0·80	..	0·1

1918-19	Nov.	Dec.	Jan.	Feb.	March	April	May
Baluchistan.							
Pasni .	..	..	6·80	1·67	..	0·05	..
Panjgur .	0 06	0·61	1·16	0·40	0·58	0·12	0·01
Quetta .	0·07	2·40	0·85	1·15	0·58	0·78	0·93
Chaman	..	2·86	0·94	0·76	0·70	0·08	0·59
Nushki .	..	2·40	1·90	2·24	0·70	0·07	0·08
Loralai .	..	0·21	0·45	0·45	0·11	0·58	2·92
Sind.							
Karachi .	..	0·18	0·67	0·10	..	..	..

Rainfall in January and February fairly good in S. Iran; the winter rain was moderate in Oman; in Baluchistan, rainfall in January and February fairly good, and fairly heavy at Pasni in January.

II—*Monsoon Rainfall 1919 (in inches)*

1919	May	June	July	Aug.	Septr.
Sind.					
Karachi	0·25	..	3·68	0 50	..
Mithi	0·26	0·30	13·20	5·24	0 04
Chachro	0·10	..	7·54	3·36	..
Rajputana.					
Barmer	0·19	..	7·38	5·92	..
Jodhpur	0·70	0·03	3·16	2·67	0 99
Jaisalmer	0·67	..	0·93	2·00	..
Bikaner	0·65	..	0·66	7·90	7 84
Punjab.					
Hissar	0·71	0·16	3·84	2·96	1·38

The monsoon began rather late: the rains were fairly plentiful in July and August in Thar and Mallani areas, but rather poor in Jaisalmer, Jodhpur and Bikaner areas. There was little rainfall in September except in Bikaner which had heavy rain.

B. Locust Data 1919

I. *Winter 1918-1919*: No records.

II. *Spring 1919*: *Iran.* Locusts were reported to have been plentiful in Shiraz in March, but found only in small numbers in Sarhad.

Baluchistan. There were no over-wintering locusts anywhere in Baluchistan. The earliest report of the appearance of locusts in Chagai was on the 8th April when they were reported from Padag near Dalbandin. In the course of the month, locust swarms were found in Chagai, Dalbandin and Padag circles in Dalbandin tahsil and in all the circles of Nushki tahsil. as also in the southern parts of Kharan. Eggs were laid in various parts of both Chagai and Kharan. By the 24th April, swarms had reached Sarawan, where they were reported from Mastung, Pringabad and Tiri. By the end of April, locusts visited Chad in Surab niabat in Jhalawan and laid eggs there.

On 1st May, a small flight of locusts reached the Fort Sandeman tahsil of Zhob district. On the 6th a swarm passed through Killa Saifulla from east to west. On the 2nd May, locust swarms were reported from Chaman area, where they were said to have reached Khwaja

Amran Hills, and eggs were said to have been laid in the Registan area in Amir's territory. Locusts were also noticed in various places of Pishin tahsil, and at Sariab (flying north to south) on the 15th in Quetta tahsil. By the middle of May, swarms were reported from Bhag and Gandhawa niabats in Kachhi.

Sind. Western flights reached Sind during the third week of May but were recorded only from Kohistan in Karachi district.

Punjab. Locusts crossed the Alipur tahsil in Muzaffargarh district in May 1919, causing a little damage to cotton fields.

III. *Summer 1919*: (June—August 1919)

Late Spring Breeding. Eggs were laid in May in Upper Baluchistan and hoppers became adults by the end of June. Breeding occurred in Quetta-Pishin district (Pishin tahsil); Zhob district (Killa Saifulla and Fort Sandeman tahsils); Loralai district (Duki tahsil); Jhalawan (Sorab niabat); and Chagai district (Nushki tahsil).

Summer Flights. From the middle of May, several swarms were found passing over various parts of Baluchistan: Chagai, Jhalawan (south-west to north-east Gidar to Zehri); Mekran (Awaran); Sarawan, Kachhi (from north to east); Quetta, Sibi, Loralai (Barkhan), Sarawan (Kirdagap).

In July swarms were found in Kachhi, Loralai and Jhalawan areas.

Summer Breeding. In August hoppers were found in Sibi district in Kach-Ahmadun-Gogai-Tangi valley, swarming in large numbers, among the crops.

No information for Sind, Punjab or Rajputana.

IV. *Autumn 1919*: (September—November 1919)

No recorded data.

Summary of Events for 1919

(1) Winter-spring rainfall was fairly good in January and February in southern Iran and British Baluchistan.

(2) There was no over-wintering in the Indian areas, but apparently locusts were present in winter and spring in southern Iran and Oman.

(3) Flights of yellow locusts reached Kharan and Chagai in April and spread by the end of the month into Sarawan and Jhalawan. By May, swarms reached Quetta-Pishin, Zhob, Loralai, Sibi, and Kachhi areas and laid eggs in various places.

(4) Western summer flights began by middle of May and passed over Mekran, Jhalawan, Kharan, Chagai and various parts of Upper Baluchistan. They reached Sind (Karachi district) by middle of May and the Punjab (Muzaffargarh district) about the same time.

(5) Spring breeding continued in Upper Baluchistan till the end of June. Light summer breeding occurred in Kach-Ahmadun area in Sibi district in August.

(6) There is no information regarding swarms in Sind, Punjab or Rajputana during summer and autumn.

(7) The monsoon was fairly heavy in many parts of Rajputana during July and August, but only *solitaria* breeding probably occurred.

(8) There were no autumn flights.

General Remarks

The locust cycle of 1912-1919 began in the autumn of 1912, and the infestation continued in fairly great intensity during the years 1913 and 1914, but practically came to an end in 1915 in India. Although, in 1915, the spring breeding in the winter brood areas was fairly heavy and the summer flights from the west were very numerous, there was no summer breeding of any consequence anywhere in India, on account of drought, so that there was an almost complete absence of autumn flights in the east as well as in the west. All the same, however, summer flights appeared from the west in June 1916, but the summer breeding of 1916 was, however, of limited extent. The flights in 1917 and 1918 were few, and although in 1919 fairly extensive spring breeding occurred, there was no summer breeding, and this presumably brought the cycle to an end.

Information in regard to Extra Indian Areas

Maxwell-Darling [1936] wrote as follows in respect of the 1912-1915 infestation in Sudanese-Arabian region: "According to the records accumulated in the Imperial Institute of Entomology, and communicated to the author by Dr. Uvarov, an outbreak of the Desert Locust in the Sudanese area began in 1912, when swarms appeared in Eritrea and Italian Somaliland. In September 1913, some swarms were present in the interior of Sudan and in Kenya; in 1914 swarms appeared in Egypt. By 1915, the outbreak developed on a very large scale. It will be seen from the Chart (fig. 3) that the beginning of this outbreak also coincided with two exceptionally rainy winters on the Red Sea Coast."

According to Fletcher [1931], there were small invasions in Egypt in 1914, large invasions in Egypt and Syria in 1915, and infestations in Egypt, Sudan and East Africa in 1916. In 1919, large swarms occurred in Iraq in April-May. Bodkin [1929] refers to a terrible infestation in Palestine during the spring of 1915, when large swarms invaded the country from Egypt and perhaps Arabia and laid eggs in enormous numbers. A month or two later, the whole country appeared to be carpeted with masses of black hopper bands and all garden and fruit trees were destroyed.

In regard to Persian data for this cycle, Predtechensky [1935] gives the following notes: "During this period—1913-1916, mass invasions of the locust and mass hatchings of hoppers were observed in Khorasan (Turbat-i-Haidari—Birjand regions), in Baluchistan, in western Persia (Kermanshah-Sultanabad regions), in central Persia (Isfahan and Yazd regions), in Arabistan (Dizful region), and in Fars (Shiraz region). The invasion is remembered by many Persian inhabitants. No doubt there were locusts in other regions of Persia adjoining those mentioned above, but unfortunately there is no record about it. Among the Orthoptera collected by Nesterov in the spring of 1914 in eastern Iraq close to the Persian Frontier, are to be found specimens of the desert locust from several localities, according to Uvarov (1916)".

According to King [King, 1929], "from 1899 till 1917, swarms of locusts occurred annually in the province of Sudan, but there followed a period of 10 years during which the Sudan suffered no damage from the pest. In 1927, and again in the following year, the locust re-appeared as a plague".

SECTION IX—PERIOD 1888—1907

CHAPTER I

LOCUST CYCLE 1888—1899

SUB-PERIOD *1888—1895*

EXCEPT for a few swarms which appeared in the Wadhwan area of Western India States in October-November, there was no swarn activity during the year 1882, and with this, the previous locust cycle of 1876 to 1882 came to an end. Then followed a swarm free interval of 5 years 1883 to 1887, during which no information on locusts is on record, though presumably the *solitaria* locust may be considered to have pursued its normal annual course of development in its natural habitat, breeding alternately in the winter-rain and summer rain areas, as observed during the recent interval of 1932 to 1939.

In the year 1888, small swarms appeared in July in the Hyderabad district of Sind, but there is no record to show what happened to them. In the year following, 1889, great flights appeared all of a sudden in June in Sind and Rajputana and started a new cycle of infestation in India which apparently continued for nearly nineteen years with hardly any real break except for three short periods of a marked diminution of activity during the years 1894 to 1895, 1899 and 1904 to 1905.

It was fortunate that by the time the swarms of 1889 appeared, the Indian Museum, Calcutta had undertaken work on Economic Entomology in India, and Mr. E. C. Cotes, who was the Entomologist in charge of this work, was the first to make an exhaustive study of the movements of locust swarms in India and his reports on the locust outbreak of 1889 to 1892 form an outstanding contribution to the study of the locust problem in India [Cotes, 1891 and 1893]. The files containing the records of detailed information on locusts during those years, on which Cotes' reports were based, have unfortunately been destroyed and it is, therefore, regrettable that his data are not available for re-examination in the light of the vastly improved knowledge of locusts and their behaviour of the present day.

YEAR 1888

A.—WEATHER NOTES

I. Winter-Spring Rainfall 1887-1888 (in inches)

1887-1888	November	December	January	February	March	April
Iran :						
Bushire	1·12	7·16	4·89	2·13	0·23	0·42
Baluchistan :						
Quetta	..	0·36	5·27	1·56	1·05	..
Kalat	..	0·20	4·14	4·16	0·81	..
Sind:						
Karachi	..	..	2·81	0·86	..	..

Data for Mekran, Jask or Muscat are not available. Apparently there was good rainfall throughout Persian and British Baluchistan in January and February.

II. Monsoon Rainfall 1888

1888	May	June	July	August	September
Sind:					
Karachi	..	..	0·18	0·98	..
Mithi	..	..	3·26	1·78	..
Umerkot	..	..	0·70	3·27	..
Rajputana:					
Barmer	..	0·20	0·17	2·46	..
Jodhpur	..	..	1·44	13·99	..
Jaisalmer	..	0·60	0·64	2·26	..
Bikaner	..	2·32	1·94	7·12	..

Monsoon rainfall in the desert was much below average except in Bikaner and was more or less confined to July and August. September being quite dry.

B. LOCUST DATA 1888.

1. *Winter* 1887-1888: No data.

2. *Spring* 1888: No data.

3. *Summer* 1888:—The only data on record are in regard to the Hyderabad district of Sind (which, however, was at that time comprised of three districts of the present day; Hyderabad, Thar-Parkar and Nawabshah). Locusts were reported from Dero Mohbat during week ending 3, July, *i.e.*, probably at the close of June, and also from four talukas including Naushahro (where indigo cultivation was damaged) during the following week.

4. *Autumn* 1888.—No records.

Summary of Events in 1888.

(1) As the winter-spring rainfall was fairly heavy, it may be presumed that outbreak centres had developed in Iran, Oman and Baluchistan, and that locusts, in the form, probably, of loose flights of individuals had migrated into India at the end of June and the beginning of July.

(2) It is probable that the migrants like those reported from Dero Mohbat had duly reached the desert areas of Sind and Rajputana, but owing to the poor monsoon rainfall (especially in July) had not bred in sufficient numbers to assume the size of swarms. Autumn migration was possibly of the solitary type.

YEAR 1889

A.—Weather Notes 1889

I. *Winter Spring Rainfall* 1888-1889 (*in inches*)

1888-1889	November	December	January	February	March	April
Iran :						
Bushire	2·37	1·13	(data not available)			
Baluchistan :						
Quetta	0·04	0·54	0·78	0·28	1·57	1·83
Kalat	0·66	0·42	2·26	1·69	0·53	0·27
Sind :						
Karachi	..	..	..	0·09	0·27	..

Rainfall data for Bushire, Jask and Muscat and for Mekran stations are not available, but conditions in Oman and south Persia during January, February and March, were presumably favourable for spring breeding.

II. *Monsoon Rainfall* 1889

1889	May	June	July	August	September
Sind :					
Karachi	..	0·52	1·26	1·19	..
Mithi	..	0·26	4·07	1·82	0·32
Umarkot	..	..	2·74	2·68	..
Rajputana :					
Barmer	3·10	3·60	0·32	3·71	..
Jodhpur	0·34	2·41	1·35	4·29	0·34
Jaisalmer	0·08	1·99	0·73	6·30	..
Bikaner	1·03	0·40	2·99	8·46	0.08
Jaipur	0·32	4·26	4·55	14·54	0·03
Ajmer	1·25	3·99	4·00	12·65	0·20
Brinpura	3·23	7·52	1·32	6·54	0·80
Punjab :					
Hissar	0·90	0·90	3·04	9·50	..
D.G. Khan	0·50	0·20	..	1·27	..
D.I. Khan	0·05	..	2·59	0·35	0·21

Pre-monsoon showers fairly good in May and June; monsoon rather light in the desert, except for heavy precipitation in August; little rain in September.

B. Locust Data 1889.

I. *Winter* 1888-1889.—No records.

II. *Spring* 1889.—No data.

III. *Summer* 1889.—(June to August 1889).

Summer Flights from the west.—

Sind. The first flight of the season was recorded at Kandiaro (near Naushahro) during week ending 18 June 1889. During the succeeding week locusts were sighted at Johi (Karachi district) and in Shahdadkot taluka in Upper Sind Frontier coming from the west. During July and August further swarms appeared in Sind.

Rajputana. According to Cotes [1891], 'Locusts were first reported in June 1889, when flights were observed in Sind and also in the Jodhpur (Marwar), Jaisalmer and Sirohi States of Rajputana.' Apparently swarms had entered Sind and Bahawalpur from the direction of Baluchistan (no information being available for this area), and thence penetrated into Marwar, Jaisalmer and Bikaner States during June. In Bikaner, they are said to have appeared from a westerly direction in the central tahsils of Bikaner and Lunkaransar and in the northern and north-western tahsils of Mirzawala and Anupgarh, spreading afterwards over the greater portion of the State. Swarms probably reached Jaipur and Ajmer areas in July.

Western India States. Flights appeared at the end of June and the beginning of July in Gujarat. Locusts passed through Prantij into Idar and through Sanand into Kadi.

Summer Breeding. With the fall of sufficient rainfall, breeding would appear to have commenced by end of June (Sirohi) and the beginning of July in Marwar and Ajmer, and to have continued during July-August in Bikaner, Jaipur and Marwar areas.

Breeding also took place in Gujarat. There being good rainfall, eggs were apparently laid in July and hoppers appeared in various places: Modasa Ahmedabad, Panch Mahals, Kalol, Dohad, etc., during August and September.

Punjab. Flights apparently were seen in July in Shahpur district and in August in Dera Ismail Khan district, where eggs were also laid.

Baluchistan. Very little information is available in regard to the activities of locusts in Baluchistan during 1889. According to Cotes, however, there is evidence to show that hoppers had been present in the Registan desert in the Kandahar area of Afghanistan during the summer of 1889. A study of the history of such invasions of Kandahar area during the more recent locust outbreaks of 1912 to 1915 and 1926 to 1931, would indicate that swarms of overwintered locusts had probably migrated from South Persia into the Kandahar areas in April, and that in view of the good rainfall received in the latitude of Quetta during the spring months, oviposition and breeding had occurred in the Registan desert (and probably also in the Chagai area) during May and June, leading to the formation of large swarms as the result of such late spring breeding.

During August, it is seem from the Sind season reports that locust swarms had visited the Hab Tapa more than once, from which it may be presumed that the Lasbela state which adjoins the Hab area of Karachi had also been invaded at this time, though, owing to the deficiency of rainfall, breeding could not have occurred there.

IV. *Autumn* 1889. (September to November 1889).

Summer breeding.—The early summer breeding, which had been induced by the fairly good falls in June in the Marwar and Ajmer-Merwara areas, was apparently not followed by further egg-laying as the rainfall in July was very defective in western Rajputana. But the rains in August were heavy all over the desert and in the Punjab, and as a result a *second instalment of breeding* occurred in parts of Marwar and Ajmer: the whole country seeming to be covered with masses of locusts

just hatched at the end of Sepetmber 1889. As the August rainfall was widespread, it is not unlikely that some breeding had been induced in the Bikaner, Jaisalmer and Jaipur areas also, but there is no positive information. In the Punjab, according to Cotes [1891], oviposition occurred in the Dera Ismail Khan and Dera Ghazi khan districts in September. From the second note on locusts issued by Cotes in February 1890, it is seen that specimens of hoppers had been received from Karachi in October, so that there seems to have been some light breeding in Karachi district also.

Autumn Flights: Sind. Numerous flights are recorded in Sind from all parts of the Province during autumn months, generally causing damage to the standing crops. Though there is no indication as to the direction of flights, there is little doubt that, as usual in autumn, the general trend was westwards in the direction of Baluchistan and Iran.

Baluchistan. It is stated that Lasbela State suffered considerable damage from the numerous swarms that pervaded the country during the autumn. In September, flights were said to have been present in British Baluchistan (perhaps Quetta-Pishin and Thalchotiali districts). According to Cotes [1891], swarms were reported in December from various parts of Baluchistan along the Harnai route between Sibi and Sharigh, from Khost, Harnai, etc.

Punjab. In September, there were flights in Hissar and Gurgaon and presumably also in Rohtak, Delhi and Karnal. Swarms were also found in parts of Jhang (Shorkot and Jhang), Shahpur, Multan and Dera Ismail Khan (Leiah). In October flights were reported from Shahpur, Multan, Dera Ghazi Khan and Muzaffargarh, and presumably occurred also in other districts of central and north-western Punjab.

Rajputana. The hoppers of the early summer brood (June to July) became winged early in September and began to fly about during that month. They were found in large numbers in October and November in most of the states of Eastern Rajputana: Alwar, Bharatpore, Dholpur, Kerowlee, Kotah, Bundi, Tonk, Shahpur, Jhalawar and Jaipur, as well as in the western states of Marwar, Sirohi, Jaisalmer and Bikaner. In the eastern states, the direction of flight was generally, towards the east and south-east, and swarms generally passed into the *United Provinces* (known then as North-west Provinces), and into *Central India* (Goona Agency, Barwani, Bhopawar and Jhabua) during the period September to November. In the United Provinces, locusts spread during October, November and December over 26 districts, the easternmost limit being Azamgarh (83°E Long.). During December, the swarms would appear to have penetrated the hill districts of Kumaon (Nainital) and Garhwal.

Towards the close of September swarms were reported from parts of Ahmedabad and Kaira districts and from Western Kathiawar, (which came probably from the Rajputana area). In October and November, flights reached Amreli in Central Kathiawar and the Broach and Surat districts, the northerly winds commonly prevailing at this period being favourable for their spread. Swarms also reached Khandesh district (Bombay Presidency) in September, presumably from Barwani side in Central India, and passed over Chopda and Erandol talukas. In the second week of October, they were reported from Nasik taluka and in the fourth week damaging *bajri* in Rahuri taluka of Ahmednagar district. In this connection, it may be noted that under the influence of a Bay depression crossing the Ganjam Coast on the 18th September, north westerly winds prevailed in general in the third week of September in the Ahmedabad area, in Central India and in Khandesh. A somewhat similar situation was met with in the 3rd and 4th weeks of October, when under

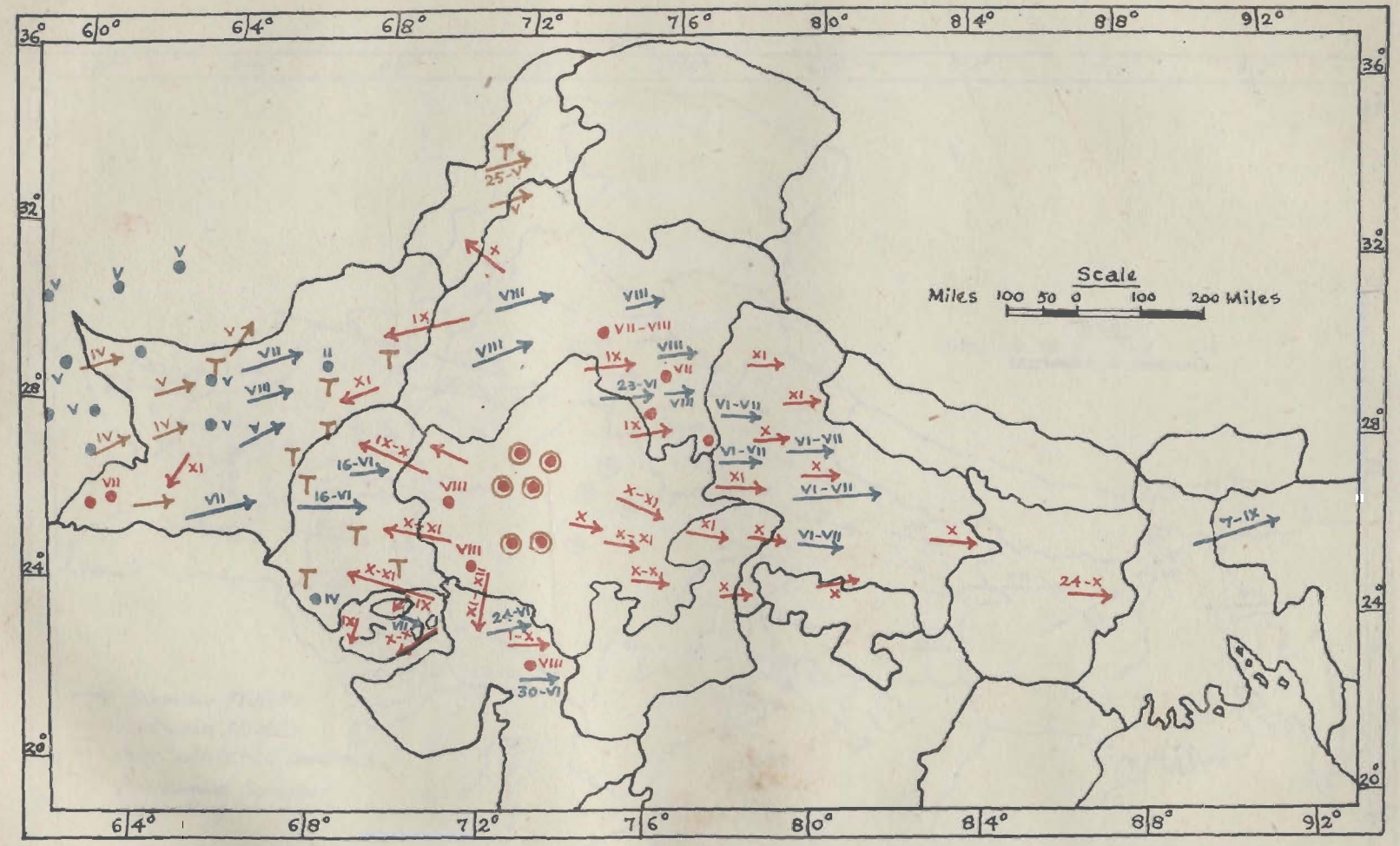


FIG. 1 LOCUST SITUATION IN INDIA IN 1914

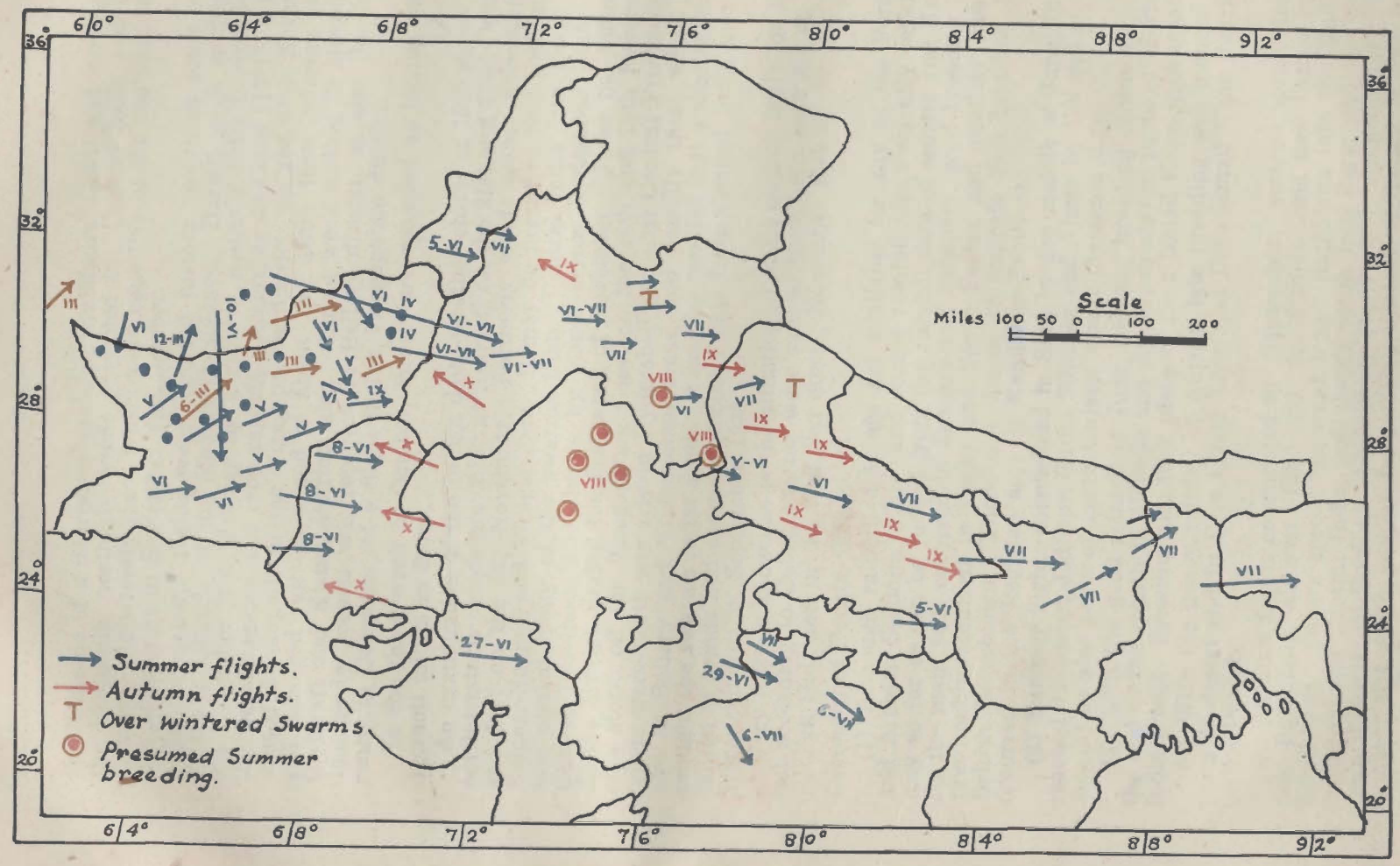


FIG. 2 LOCUST SITUATION IN INDIA IN 1915

the influence of a depression crossing the Madras Coast and moving into the Peninsula, northerly winds prevailed in Central India and North Bombay. Apparently these winds were causative of the southern migration of swarms in September and October.

In November, flights were reported further south in some of the northern districts of the *Madras Presidency*. During week ending the 9th November 1889, damage by locusts in Kistna district is recorded in the weekly season and crop reports. According to Cotes [1891], a flight visited Anakapalli in the Vizagapatam district on the 18th November and damaged *raji* crops and at about the same time swarms visited Godavari and Kistna districts also. During week ending 23 November, damage by locusts was reported in Bellary district, as also the occurrence, in December, of a flight in the Vizagapatam district.

In the third week of October, locusts are recorded as having visited Amraoti taluka in *Berar*.

An examination of the Indian daily weather charts of 1889 shows that north-westerly winds prevailed at Amraoti on the 21st and 22nd October, and that on the 6th November, northerly winds were noticeable at Raipur, Nagpur and Vizagapatam. It may be presumed that such winds had carried many of the swarms from Central India into Berar and Central Provinces, and thence by stages across Hyderabad State into Kistna district, during the first week of November. Under the influence of a storm off the Vizagapatam Coast on the 18th and 19th November, winds were north-westerly in Hyderabad and east Central Provinces, as also in Bellary and Vizagapatam areas, and possibly these winds had brought the swarms so far south. It may be recalled that a similar distribution of winds had conveyed locust flights from Central India into the Warangal area in September 1930.

Very little is known as to the situation in areas outside India for 1889, but according to Cotes, swarms were said to have been seen all up the *Persian Gulf* and in the *Red Sea* during November 1889.

Summary of Events, 1889.

(1) Although rainfall data are not available for any of the Persian and Arabian Stations, winter and spring rainfall was evidently satisfactory so far as can be judged from the rainfall data of Quetta and Kalat. As the main falls occurred in January and February, good breeding had presumably occurred in Oman and South Persia, and possibly also in British Baluchistan. There is evidence to indicate that breeding had occurred in the Registan area of Kandahar Province.

(2) Summer flights commenced in Sind by the middle of June; these reached Jaisalmer, Jodhpur, Sirohi, Bikaner and Ajmer by the end of the month; as also parts of north Gujarat about the same time.

(3) With the good rainfall of June, summer breeding commenced by the end of the month in Marwar and Ajmer, as also in parts of Western India States. Breeding also took place in Dera Ismail Khan in August.

(4) With the heavy rainfall of August, late breeding was induced in parts of desert and in Dera Ghazi Khan and Dera Ismail Khan districts in the Punjab.

(5) Autumn flights commenced in September; swarms spread from west Rajputana all over Sind and the Punjab and flew thence into Baluchistan. Others spread eastward from Rajputana into the United Provinces and Central India, and thence south into Berar and the northern districts of Bombay (Khandesh, Nasik and Ahmednagar) by October, and south east as far as Vizagapatam, Godavari, Kistna and Bellary in Madras Presidency in November. In the United Provinces the easternmost limit was Azamgarh.

YEAR 1890

A. Weather Data 1890

I. *Winter-Spring Rainfall 1889-1890 (in inches)*

1889-1890	November	December	January	February	March	April
Iran :						
Bushire	..	0·02	2·07	1·87	2·61	2·12
Baluchistan :						
Quetta	..	..	0·83	0·46	0·81	1·62
Kalat	..	..	0·50	0·18	0·78	1·62
Sind :						
Karachi	..	0·03	..	..	..	..
Jacobabad	..	.	..	..	0·02	0·06
Punjab :						
Peshawar	..	0·02	0·50	0·23	0·95	1·89
Bannu	..	..	1·00	0·13	3·08	2·26
Rawalpindi	..	..	0·74	1·06	1·78	1·57

The winter rains were much below average. Fairly good rain fell only during April on most places.

II. *Monsoon Rainfall 1890 (in inches)*

1890	May	June	July	August	September
Sind :					
Karachi	..	0·05	2·90	4·09	..
Mithi	..	0·72	4·52	1·48	0·10
Umerkot	..	..	6·10	2·37	..
Rajputana :					
Barmer	..	1·83	5·65	5·23	0·53
Jodhpur	0·40	2·47	5·78	3·36	2·16
Jaisalmer	..	0·16	2·61	2·80	..
Bikaner	..	1·23	2·89	1·07	..
Jaipur	0·02	2·60	8·06	6·66	3·49
Ajmer	1·25	1·77	4·35	4·14	1·48
Punjab :					
Hissar	1·29	2·50	3·70	1·02	0·58
Delhi	0·52	1·67	13·85	8·98	2·23
Ferozepur	..	2·63	6·00	4·28	0·57
Lahore	..	3·35	11·27	7·38	0·25
Rawalpindi	1·59	1·17	21·06	15·04	0·75
N. W. Frontier Province :					
Peshawar	0·20	..	1·47	1·94	0·02
Bannu	..	0·33	1·86	2·85	..

A fairly normal monsoon: in the desert, there were a few showers in June, rainfall was considerable in July and August: very little in September.

B. LOCUST DATA 1890 (*vide* Pl. 57)

I. *Winter* 1889-1890. (December to February).

Overwintering swarms were found in Sind and parts of the Punjab, and stray swarms in the United Provinces, Rajputana and Madras in January. Big flights were also said to have been reported from Baluchistan. The presence of such over-wintering locusts in Sind and Punjab is to be correlated with the occurrence of late breeding in 1889.

Sind. Swarms were found moving about in most parts of Sind, generally flying east to west often damaging early *rabi* crops.

Baluchistan. In February, swarms visited Duki Tahsil in Loralai district and Khost and other places in Sibi district and damaged crops. Some flights also occurred in January, according to Cotes [1891].

Punjab. In January-February, flights of locusts were seen moving from Kashmir territory into Rawalpindi district and thence into Hazara district to the north and into Jhelum district to the south. Swarms were reported from Dera Ismail Khan, Bannu and Shahpur districts, in the north, and from Lahore, Muzaffargarh, Amritsar, Ferozepore and Dera Ghazi Khan in the south.

According to Cotes [1891], a few flights were reported in January from Agra in the United Provinces and from Ajmer-Merwara in Rajputana and a single flight in Kistna district in Madras Presidency.

Situation in Extra-Indian Territory.—

According to information collected by Cotes[1891], flights were present at Sharjah on the Persian Gulf in September, 1889, and eggs were laid there (which is rather unlikely as September is too dry for breeding) Locusts were said to have appeared in Kishm Island in October 1889, and to have been present all over the Persian Gulf in November and December. They were reported to have bred in Bahrein Island in February 1890, and possibly breeding had occurred at this period also in Oman territory, as good rainfall had been received in January and February in the Persian Gulf region. In deed under date 25th March 1890, the Residency Agent, Arab Coast had reported that 'locusts had appeared at places on the Oman Coast'. Swarms were observed also in Persian territory in March.

II. *Spring* 1890. (March to May 1890).

Sind. Flights were reported early in March from Upper Sind Frontier, where the direction of movement was from east to west, and from Shikarpur district. By end of March, hoppers had hatched out in great numbers in the Larkana, Kambar and Nasirabad tahsils of the Shikarpur district and were being met with throughout April.

Punjab and N. W. Frontier. Flights were found in Hissar, Patiala and Karnal in the south, and in Shahpur, Rawalpindi, Jhelum, Bannu, Hazara, Peshawar, Kohat, Dera Ismail Khan and Amritsar in the north. Egglaying occurred in Rawalpindi, Peshawar, Kohat and Jhelum districts and control measures in the shape of egg collection and hopper destruction were said to have been taken. Hoppers escaping destruction may be presumed to have attained wings by middle of May.

On 31st May, a flight of locusts was reported to have passed over Alwar from north to south, and is evidently referable to the generation bred in the Punjab passing south or south-east into Rajputana.

III. *Summer* 1890 (June to August 1890).

Summer Flights: *Sind.*—The first flights from the west were signalled during the week ending 27th May in Upper Sind Frontier at Thul passing west to east to Kashmore, and also in Hyderabad at Sakrand. During June and July, numerous flights were reported in almost all the districts of Sind.

Punjab. The first flights were noticed in Hissar during June and in *Rajputana,* swarms were first recorded in Vinjorai in Jaisalmer by the beginning of June, and in Sirohi on the 2nd June; and in Bikaner the first flight was seen in the Reni Nizamat on the 23rd June 1890. Subsequently they were reported from various localities in Marwar, Bikaner, Jaisalmer and Sirohi. In Alwar and Dholpur also flights occurred in the first and second weeks of June.

United Provinces. Eastward flight were reported during the first week of June, swarms passing eastwards across the province up to Fyzabad district. Further flights continued during the rest of the month, the easternmost limit being Azamgarh district. (83°E. Long.) By August, however, reports of locusts were limited to those from Agra, presumably because the swarms had drifted westwards during the prevalance of easterly monsoon winds.

Central Provinces. During the last week of June, flights passed over Khurai tahsil of Saugor district.

It is thus seen that summer flights reached as far east as Azamgarh district in the United Provinces and as far south as Saugor district in Central Provinces by the end of June.

Summer Breeding.—

Punjab. As rainfall was satisfactory in July and August in most districts, breeding occurred in many places. In the south, breeding occurred in Hissar, Gurgaon, Ferozepur and Delhi, and in the north in Bannu, Peshawar, Kohat and Amritsar. Hoppers were seen till the end of September.

Rajputana. There was good railfall in July and August and egglaying occurred in Jodhpur, Ajmer-Merwara, Bikaner, Sirohi, Alwar and probably Jaipur areas during July to August. In August it was said that huge numbers of young locusts were present all over these areas. In the vicinity of Jodhpur, it would appear that hoppers were in such enormous number in August as 'often to delay the arrival of trains by the greasiness they caused on the railway lines.' According to Cotes [1891], very extensive breeding of young locusts took place in the Jodhpur and Bikaner States, and in his opinion, 'it is these insects that comprised the flights that afterwards invaded the Central Provinces, Bombay, Madras and Bengal.'

Sind. There is no indication in the season reports of the Sind Official Gazette as to the occurrence of breeding in the Thar area, but there was appreciably good rainfall in Sind and as under similar climatic conditions heavy breeding had occurred in Mallani, locust multiplication had no doubt taken place there too. Possibly some oviposition had also occurred in parts of Karachi, as there wts good precipitation in August.

Baluchistan. There is information on record that good rain had fallen in July and August throughout Lasbela State causing much grass to spring up, and that locusts had invaded the district in large numbers, causing damage to crops. As under these conditions oviposition usually takes place, breeding had presumably occurred in this area to a certain extent.

Situation outside India.

According to Cotes [1891], locusts were reported by the Political Resident in Turkish Arabia, to have appeared about Baghdad in Iraq about the middle of June and done some damage to gardens and date trees. According to the report of the British Agent, Shiraz, for the week ending 21st June 1890, large swarms of locusts had appeared in districts around Shiraz and had done much harm to the crops and gardens. Cotes [1891] mentions that S.S. *Yang-tse* had passed through vast masses of locusts found floating over some 300 miles of her course in the Red Sea, during June 1890. Again, in August 1890, the P. and O. Ship S.S. *Rome* is reported to have passed through vast flights both along the shores of Arabia near Aden and also for two days after entering the southern portions of the Red Sea.

IV. *Autumn* 1890 (September to November 1890).

Summer Breeding. Breeding continued till end of September; there was no late breeding as little rain fell in September. The new generation of winged locusts began flights during September.

Autumn Flights. Rajputana. Flights were reported from Sirohi, Harowti and Tonk, Alwar, Partabgarh and Bikaner during the autumn months. The direction of flights was generally west to east or northwest to southeast or south in the eastern States of Rajputana. In Sirohi, the most common direction was towards the south and in Bikaner towards north. Damage to various crops such as maize, *Bajri*, cotton and *til* was reported in many places.

Sind. Numerous flights were reported from most parts of Sind during the autumn, the general direction being east to west, or north-east to south-west, only slight damage to crops being reported.

Baluchistan. There are no records except for Lasbela where much damage to crops by locust swarms is said to have occurred. Evidently all the flights from Sind should have passed through Baluchistan into Persia.

Punjab. Hoppers were found in Ferozepore during September. Swarms were reported from many of the central and eastern districts in September, but in October and November the activity of swarms had shifted north and north-west into Rawalpindi, Shahpur, Bannu, Dera Ismail Khan, Hazara, Kohat and Peshawar districts, and also to Jhang and Muzaffargarh to the west. Swarms also entered the hills in Kangra, Simla and Bashahr areas in November.

United Provinces. Swarms began to enter the Province by end of September and during October, they had spread eastwards up to Fyzabad district. Some flights also reached the hills in Kumaon district (Nainital), and were found passing and repassing across the outer Himalyan Ranges. Swarms were apparently present in most of these places till December.

Central India. Reports of crops damaged by locusts were received during the last week of September from Bhopal and Western Malwa, and during October from parts of Goona and Bhopawar Agencies. In November some flights were seen in parts of Gwalior.

Central Provinces. During the last week of September, swarms were reported from Hoshangabad, Nagpur and Balaghat districts Cotes [1891], and during October swarms passed into Seoni, Chhindwara, and Bhandara districts to the south and into Saugor, Jubbulpore, Bilaspur and Raipur districts to the south-east. They also appeared in all the four districts of Berar. The swarms found in Berar and western Central Provinces would appear to have migrated partly into Bombay, partly south into Hyderabad and north Madras. The flights reported from the eastern districts would seem to have passed eastwards into Bihar and Bengal and south-east into Sambalpur and Ganjam districts in Orissa.

Bombay Presidency. Locusts first appeared in Bombay, during the second week of September in Jambusar in Broach district, but soon disappeared. In November swarms again appeared and spread into Rajputana, Baroda and Surat areas. According to Cotes [1891], locusts also appeared in Mahikantha area; presumably all these swarms had been derived partly from Sirohi and partly from Central India.

Towards the last week of October, swarms were reported in Ahmednagar district in the north and in Dharwar district in the south. In both cases, they had presumably been derived from the Berar area *via* Hyderabad territory. In the north, flights spread westwards into Nasik, Thana, Poona, Sholapur, Satara, Kolaba and Ratnagiri districts during November. In the south, swarms had entered Bijapur from Gulbarga and Raichur districts of Hyderabad, and spread into Belgaum, Dharwar and Karwar districts. From Ranibennur in Dharwar district a flight is said to have passed towards Shikarpur in Mysore territory in November.

Madras Presidency. Fairly detailed data on the movements of swarms in Madras are available in the weekly Season and Crop Reports of the Fort St. George Gazette for 1890. The earliest information about the entry of swarms is for the week ending 25th October 1890, when they were reported from Chicacole taluk of Ganjam, from Sidhout and Pullampet taluks of Cuddappah (damaging indigo and *ragi*), and from Nandikotkur and Markapur taluks of Kurnool. During the succeeding weeks, locust flights or damage were reported from other parts of Cuddappa (Badvel, Rayachoti, Madanapalle, Vayalpad and Cuddappa taluks), from North Arcot (Chittoor, Palmaner, Punganur, and Maderpauk taluks), from Bellary (Bellary, Kudligi and Hospet taluks), from Anantapur (Tadpatri, Anantapur, Hindupur and Madakasira taluks), from Nellore (Kandukur, Nellore and Kota), and from Chingleput (Tiruvallore taluk). From a study of a chart of these reported movements of locusts in Madras, it would appear that the infestation reported from Chicacole (Ganjam district) had probably been derived from Sambalpur (C.P.), that the movements in Kurnool and Cuddappa had originated from the Raichur—Mahbubnagar area of Hyderabad and spread into Nellore to the east and to North Arcot and Chingleput to the south and that the swarms in Bellary and Anantapur had come from the Dharwar infestations. It is likely that, since Kudligi, Hindupur and Madakasira areas were affected, the adjoining parts of Mysore, *viz.* Chitaldroog, Tumkur and Kolar, were probably also visited, though there are no definite records. The southern-most point reached in 1890 was Tiruvallore (13°N. Lat), only a short distance from Madras City. There were no reports of locusts after the first week of December.

Bihar, Bengal and Assam. By the end of October, a swarm is said to have appeared in Aurangabad area of Gaya district and to have moved northwards. Early in November, a flight appeared at Lohardagga in Bihar. Swarms appeared at about the same time in Rangpur and Malda districts of Bengal. During the subsequent weeks flights were reported from Dinajpur, Bogra, Bankura, Howrah, 24-Parganas, Faridpore and Dacca causing damage to rabi crops. According to Cotes [1891], a stray flight is said to have penetrated up to Dhubri in Assam (91°E. Long.)

The infestation of 1890 in India was remarkable by the circumstance that the autumn flights besides affecting Sind and Punjab reached very far south (13°N. Lat.), spread all over the Bombay Presidency and the northern districts of Madras, and also spread eastwards into many districts of Bengal (91°E. Long). In an endeavour to find out if this could

be explained by weather conditions prevailing at the time, the daily weather charts of the period concerned were studied and coincidences between the locust movements and the wind directions noted.

With the withdrawal of the south-west monsoon, the normal wind movements in Central India and Central Provinces in the autumn months are directed towards the east, but between the 23rd and the 27th September, under the influence of a storm which crossed the Orissa coast on the 23rd., the winds in the Hoshangabad area became northerly or north-westerly and this should have been favourable for taking the locusts from Central India south to Hoshangabad, Nagpur and Chhindwara. During October, northerly or north-westerly winds alternated with westerlies and the former (which prevailed during the 2nd and 3rd weeks of October) were presumably instrumental in conveying the swarms into the Bombay Presidency and the Ceded Districts of Madras across the Hyderabad State, while the westerlies served to carry them into the eastern parts of the Central Provinces and thence into Bihar and Orissa. Consequently by the beginning of November, the Central Provinces were fairly clear of locusts.

During November, the normal westerly and south-westerly winds generally prevailed in the north of the Peninsula at the latitude of the Central Provinces, and carried the locusts into Bengal, while in the south, north-easterlies were common in the Bombay areas, and northerlies (often associated with Bay depressions) occurred in the northern districts of the Madras Presidency, and these were instrumental in the spread of swarms in the Bombay and Madras areas.

Summary of Events in 1890 (*vide* Pl. 57).

(1) Overwintering swarms were present in Punjab, Sind and Baluchistan; and in the United Provinces, Rajputana and Madras (Kistna).

(2) The winter-spring rainfall was fairly good and probably good spring breeding occurred in East Arabia. Breeding is known to have taken place in Bahrein in February.

(3) Spring breeding occurred in north Punjab and the North West Frontier Province, overwintered locusts laying eggs in March after good spring showers. There was also some breeding in North Sind.

(4) Punjab-bred locusts began to move down in flights towards the south-east in May and by mid-May, western swarms also began to appear in Sind and Rajputana. The combined flights reached as far east as Azamgarh in the United Provinces in June.

(5) With the development of the Bay monsoon current in July, locusts were carried back westwards into the Punjab and Rajputana, and summer breeding occurred after the fall of monsoon rain in Rajputana (Alwar, Ajmer, Jodhpur, Sirohi and Bikaner) and in Punjab (south-east and north-west Punjab and the North West Frontier Province).

(6) Autumn flights commenced in September: (1) some of the swarms passed westwards into Sind, Punjab and Baluchistan, (2) others passed eastwards across east Rajputana and Central India into (a) United Provinces, (b) Western Central Provinces and Berar; partly into Bombay territory (Broach, Baroda, Nasik, Ahmednagar, Poona, etc., up to Dharwar and Kanara) and partly into Hyderabad and the north Madras areas as far south as Chittoor and Chingleput districts and (c) into eastern Central Provinces, partly into Orissa and Ganjam, through Sambalpur and partly into Bihar, Bengal and Assam (Dhubri).

YEAR 1891

A. Weather Notes 1891

I. *Winter-Spring Rainfall* 1890-1891 (*in inches*)

1890-91	November	December	January	February	March	April
Iran :						
Bushire	1·95	6·74	7·96	0·34	0·21	0·08
Baluchistan						
Quetta	3·72	3·66	3·75	5·15	0·59	0·87
Kalat	1·80	3·11	3·43	7·21	1·63	0·29
Sind :						
Karachi	4·66	1·41	1·03	..	1·18	..
Shikarpur	3·31	1·77	0·36	0·54	0·32	..
Jacobabad	2·50	1·17	0·40	0·64	0·68	0·27
Shadadkot	?	?	0·52	0·03	0·05	0·06
Sehwan	1·89	0·68	0·97	..	0·59	..
N. W. F. Province :						
Peshawar	4·02	2·33	4·41	2·69	1·63	2·59
Bannu	2·71	0·42	2·00	1·35	1·04	..
Punjab :						
Rawalpindi	0·92	4·47	4·51	5·33	2·60	1·54
Gujrat	0·30	3·45	3·63	2·80	1·61	0·22
Lahore	0·50	2·25	3·22	0·47	2·87	0·51
Ferozepore	0·32	1·83	2·40	0·23	3·17	0·10
Jullundur	..	1·85	4·00	0·86	3·59	0·48
Hissar	..	0·33	1·61	0·13	1·21	..

The winter-spring rainfall of 1890-1891 was not only extraordinarily heavy but also remarkable for its persistency over most of the areas of Indo-Persian winter rainfall. Rains began in November 1890 and continued with unabated vigour till March 1891, and there were some falls even in April and May. Rainfall was particularly heavy in upper Baluchistan, the North West Frontier and north Punjab. It is recorded that in the Chaman tunnel area at Shelabagh in Chaman tehsil, the total rainfall from November 1890 to March 1891 was 38·32 inches as against 6·50 inches during the previous 18 months. There are no data for British or Persian Mekran or for Oman, but presumably the winter rains were heavy in these areas also.

II. *Monsoon Rainfall* 1891 (*in inches*)

1891	May	June	July	August	September
Sind :					
Karachi	..	0·01	..	..	0·20
Nithi	0·09	..	2·12	..	0·50
Umarkot	0·22	..	1·20	..	0·64
Rajputana :					
Barmer	..	..	4·13	0·23	0·86
Jodhpur	0·38	..	7·14	0·32	0·46
Jaisalmer	0·12	..	2·45	0·41	0·16
Bikaner	0·96	0·02	2·58	0·91	0·71
Ajmer	0·83	0·10	3·77	1·22	1·20
Jaipur	0·56	0·38	6·46	3·06	6·79
Brinpura	..	..	0·45	0·68	0·30
Punjab :					
Rawalpindi	1·11	0·30	1·64	11·03	1·74
Gujrat	1·12	0·23	8·89	3·46	1·29
Lahore	0·65	0·36	1·56	5·70	1·22
Ferozepur	0·36	0·20	2·78	..	1·49
Jullundur	..	0·21	2·21	6·19	1·25
Ambala	0·64	3·61	8·23	11·10	6·40
D.G. Khan	0·71	..	0·05	0·46	0·32
Hissar	0·27	0·27	2·06	0·89	4·30
N.W. F. Province :					
Peshawar	0·32	0·14	0·20	0·67	0·08
Bannu	1·45	0·26	2·29	1·16	0·35

The monsoon commenced late; there were fairly good falls of rain in July, though there was little rain in Sind and only light rainfall in almost total failure in August except in parts of the Punjab, and except for the downpour in the Delhi-Ambala-Hissar-Jaipur region, there was but little rainfall in September. On the whole, the monsoon rainfall was largely in defect especially in Sind and the north of the desert.

B. LOCUST DATA 1891.

I. *Winter* 1890-91 (December to February).

Sind. There were reports of locust movements throughout the province in the winter period up to the middle of February.

Punjab. Swarms were present in the North-West Frontier (Peshawar, Dera Ismail Khan, Bannu, Hazara and Kohat) and in North-West Punjab (Rawalpindi, Gujrat, Jhelum, Shahpur) and in Jhang and Dera Ghazi Khan. As heavy rainfall had occurred in northern Punjab and in the Frontier, oviposition commenced very early, and was reported from Peshawar in January and Dera Ismail Khan in February.

Bengal. The flights reported to have been active in December 1890 in various parts of Bengal, were still observable during January and February in the districts of Burdwan (Raneegunge, etc.), Bankura, Midnapore, Hooghly (Serampore, Hooghly, etc.) and Calcutta (in February).

II. *Spring* 1891 (March to May 1891).

Sind. After an interval of about 6 weeks, swams were reported in Sind from the last week of March mainly from Karachi (Johi, Sehwan, Manjhand Kohistan), Shikarpur (Kakar, Sharpur, Nasirabad), Upper Sind Frontier (Shahdadkot), and Hyderabad (Kandiaro). These were presumably early migrants from the west, probably representative of early spring breeding in Mekran as a result of heavy winter rainfall.

Spring Breeding. Light breeding would appear to have occurred in Karachi taluka, in Shikarpur district (Mehar and Nasirabad) and in Upper Sind Frontier (one taluk), as a result of fairly good rainfall in winter.

Punjab. Swarms were found in most parts of the Province, especially in the northern, central and eastern submontane districts.

Spring Breeding. Breeding was reported from all the five districts of the N.W. Frontier (Peshawar, Dera Ismail Khan, Hazara, Kohat and Bannu) and twelve districts of the Punjab (Shahpur, Jhelum, Gujrat, Gujranwala, Sialkot, Lahore, Gurdaspur, Hoshiarpur, Ludhiana, Ferozepore, Muzaffargarh and Hissar). Standing crops of mustard, wheat, barley, melons and sprouting kharif and cotton were attacked at various places.

Western Flights.—From the beginning of April, large swarms appeared in various places in the Punjab and obviously represented the young brood produced in Baluchistan and Iran. Towards the second fortnight of May, locusts bred in the Punjab also began to fly over the area, the general direction being south-east or east, and visited the hill districts of Simla and Kangra, and also the submontane districts of Ambala, Hoshiarpur and Jullundur.

The Punjab-bred swarms were reported from Cawnpore district in the United Provinces by the second week of May and by the last week of May the flights had reached Ballia and had passed over Purulia and Hazaribagh in Bihar.

The swarms from the west passed into Rajputana from Sind during May. By the last week of May, they had spread into Marwar and reached Alwar, Kotah and Kherwara. In the south, some swarms were reported from the Gohilwad Pranth of Kathiawar on the 27th May and a flight passed over Champaner in the Panchmahals south-west to north-east on the 28th. Locusts also appeared in Wadhwan at about the same time. Further flights were reported in Amreli district (Baroda State) and in Jhalawar and Halar in Kathiawar about the end of June.

Towards the close of May, swarms had also passed over Bhopal and Mhow in Central India and reached Jubbulpore, Hoshangabad and Nimar in Central Provinces.

Situation outside India.

There is very little information either in regard to Baluchistan or Iran as to the movements of locusts in spring. As, however, there was widespread rainfall from November 1890 to March 1891, in most of the winter rain areas, there should have been every likelihood of widespread spring breeding in British and Iranian Mekran. It was probably the adults of this early spring brood that had appeared in Sind and Punjab in April. Probably breeding had taken place also in the Chagai and Kandahar areas in April to May. According to the Kandahar News Letter dated 15th June 1891, the fields and gardens of Khakrez, Arghandab and Kashkanhud cultivators had been greatly damaged by locusts. Possibly the reference is to swarms of pink locusts from the Seistan, Garmsel and Registan spring brood areas generally found in these areas by June.

III. *Sumumer* 1891 (June to August 1891).

Baluchistan. Flights from Persia.—During May and June 1891, numerous swarms of locusts are said to have passed through Quetta-Pishin and Thal-Chotiali (Loralai and Sibi) areas and to have caused extensive damage to fruit trees and *kharif* crops. Swarms also visited the gardens at Rindli and Mach in Bolan Pass and *kharif* crops of Nasirabad taluk of Sibi (Khan's lands) in June and July and caused much damage. It is mentioned in the Report of the Forest Administration in Baluchistan for 1891—1892: "The good effect of heavy winter rains in 1890—1891 was quite counter-acted by the invasion of locusts. In the Quetta and Ziarat forest ranges, Juniper seedlings were destroyed; fruit of *Prunus eburnea* was stripped; almost all bushes as well as Ash and Pistachio trees and even Junipers were denuded of leaves. In the Sibi range, 'Jal' (*Salvadora oleoides*) 'Jand' (*Prosopis*) and 'Siris' were attacked and stripped of their leaves or fruit and poplars, willows and olive trees were defoliated".

Apparently, movements of swarms across the upland areas of Baluchistan into Sind and Punjab continued in July and August. Mr. Elliot of the Baluchistan Forest Department reported the prevalence of maggots in locusts collected on the 27th August 1891 in parts of the Sibi district.

Sind Numerous flights were reported in all parts of Sind during June, July and August, as well as damage to all standing *kharif* crops, cotton, *jowar, til* and indigo. It is recorded that in June, numerous locusts were found dying in the Upper Sind Frontier district of maggot disease.

Punjab. Western flights appeared in most of the districts of the Punjab during June. In Gujrat, for instance, large swarms passed over the district on the 11th and the 13th June, and during the next week, flights similarly appeared in Bannu district. They also appeared in the hill districts of Kangra and Simla and on the higher hills of Abbotabad tehsil in Hazara district.

United Provinces, Bihar and Bengal. During June, flights were reported throughout the United Provinces as far as Ballia district in the east. In *Bihar* swarms were found in Saran, Champaran, Monghyr, Bhagalpur, Purnea and Patna districts in the north and in Santhal Parganas, Lohardagga, Palamau, Manbhum and Singhbhum of Chota Nagpur division in the south. They also appeared towards the east in Rajshahi, Darjeeling Terai, Malda, Dinajpur, Bogra, Murshidabad, Burdwan and Midnapore districts of *Bengal.* Flights are said to have visited Jeypore estate near Cuttack and passed over Angul and Banki estates in *Orissa*, presumably being derived from Sambalpur areas of Central Provinces.

Central India and Central Provinces. By the 10th June, swarms were reported to have passed through Mhow and Bhopal in *Central India;* and other flights over Jubbulpore, Nagpur, Raipur, Bilaspur and Sambalpur districts showing an easterly trend from Rajputana towards Bihar. An examination of the India Daily Weather charts for June 1891 showed that up to the 10th, strong westerlies had prevailed in this area. During the week ending 24th June, swarms had passed through Berar over Malkapur, which would show a southerly trend in the flights and it is seen from the weather charts that northwesterly winds had been prevalent in the Central parts of the country for several days prior to the 24th June. Conditions were presumably favourable at this

period for conveying locusts (south and south-east), (1) into Hyderabad State from Berar and thence into Cuddappa, (2) into the south-eastern states of Central Provinces from Raipur and thence into Vizagapatam, and (3) into Orissa and Ganjam from Sambalpur. This would explain the reported presence of locusts in June to July in parts of Orissa and of Ganjam, and in the Vizagapatam district and in parts of Cuddappa in July.

Locusts were apparently to be seen in parts of the Central Provinces up to the second week of August.

A study of the relative position of the swarms in the United Provinces during June-July-August shows that from the middle of July, swarms were gradually advancing from east to west, in coincidence with the prevalence of south-easterly and easterly winds from the 11th July connected with the advance of the Bay monsoon. The reported occurrence of locust damage to crops in eastern Nepal during the last week of July is to be considered as a part of the westward movement of swarms. By middle of August, locusts would appear to have been confined to Agra and Bareilly.

Summer breeding.—There was little monsoon rainfall in *Sind* or *east Baluchistan and consequently there was no breeding. In regard to Rajputana*, rainfall was in great defect in Jaisalmer and Bikaner and in north Marwar, but in the south there was a considerable amount of precipitation in July and breeding is recorded as having occurred in Sirohi and damage to grass and crops was reported from Marwar and Ajmer in August and September, indicating the presence of hoppers. It is probable that some breeding had similarly taken place in Sachor, Mallani and southern parts of Marwar, and in Ajmer and Jaipur. It was only in the *Punjab*, where a considerable amount of fairly heavy rainfall was recorded in August in central and north-west Punjab and along the submontane areas, that fairly heavy late breeding occurred. Oviposition occurred in late August and during September, and hoppers which emerged were being destroyed till the middle of November. In Dera Ismail Khan hoppers were met with even in December. The districts where breeding was reported were (1) *North West Frontier*—Hazara, Bannu, and Dera Ismail Khan; (2) *North West Punjab*—Rawalpindi, Gujrat, Shahpur and Jhelum; (3) *Submontane Punjab*—Gurdaspur, Hoshiarpur, Jullundur, Ludhiana and Karnal, and (4) *West Punjab*—Dera Ghazi Khan.

IV. *Autumn* 1891. (September-November 1891).

Late Summer Breeding. As already mentioned, hoppers were present in large numbers in October and continued till November in Punjab.

Autumn flights.—Punjab. Flights were seen in October and November, but only in small numbers. In December, a few flights occurred in Gurgaon, Karnal, Jhang and Dera Ismail Khan.

Sind. A number of flights were reported from all parts of the province during September and October, but only a few in November and December from Shikarpur and Hyderabad districts. According to the Deputy Commissioner, Upper Sind Frontier, maggot attack was noted in swarms passing westward during October 1891.

Rajputana. Swarms were reported in September from parts of Marwar, Ajmer, Marwar, Jhalawar and Kotah. In November and December, locusts were reported only from Marwar and in the third week of December a flight is said to have passed over Todgarh.

In *September,* flights were recorded from *Central India* (Goona, Nimach and Bhopal in first fortnight) and from the *Central Provinces* (at Saugor in second week). In the *United Provinces*, swarms were reported till the end of the month in the districts of Banda, Jhansi and Meerut. These were probably part of the brood from the Rajputana and Punjab breeding areas.

There are no records of locust flights during autumn from any other area.

Summary of Events in 1891

(1) There was an extraordinarily heavy winter and spring rainfall in the winter rain areas—from November 1890 to March 1891.

(2) Early and heavy breeding was observed in the North West Frontier Province and in North Punjab, and it is likely that heavy spring breeding had occurred in Oman and in British and Persian Mekran, and also in Chagai and Kandahar areas in April—May.

(3) In April, swarms of early broods from the western areas entered Sind and Punjab; and by middle of May, the Punjab brood began to move south-east into the United Provinces and Central India. Further heavy flights from the west also began to appear about this time in Sind and the Punjab and spread over Rajputana and Western India States and penetrated into Central India and the Central Provinces. A great part of these swarms flew across Central Provinces into Bihar, Bengal and Orissa, and parts of Ganjam and Vizagapatam district. Other swarms took a southerly direction and flighted over Berar and Hyderabad territory into Cuddappa (and probably also Bellary) in Madras in July.

(4) Rainfall was in defect in Sind and the northern parts of Rajputana, and consequently there was no breeding. In the southern parts of the desert, there was good rainfall in July and breeding occurred in Sirohi and probably also in south Marwar, Ajmer and Jaipur. In the Punjab, there was heavy rainfall in August and late summer breeding occurred in thirteen districts of the North West Frontier Province and the Punjab.

(5) West-bound autumn flights were observed in Sind and the Punjab during September and October, but few in November—December. There were a few eastward flights in Central India and Central Provinces and United Provinces in September, but none anywhere after this month.

YEAR 1892

A. Weather Notes 1892

I. *Winter-Spring Rainfall* 1891-1892 (*in inches*)

1891-1892	November	December	January	Febuary	March	April
Iran:						
Bushire	4·37	0·49	1·82	1.00	..	0.02
Baluchistan :						
Quetta	0·13	0.21	0·75	0·88	0.78	9.07
Kalat	..	0·24	0.66	1·11	0·36	0.18
Sind:						
Karachi	..	..	0·31	..	0.07	..
Shikarpur	..	..	0·20	0.17	..	..

I. *Winter-Spring Rainfall* 1891-1892—contd.

1891-1892	November	December	January	Febuary	March	April
N. W. F. Province :						
Peshawar	0·37	..	0·19	0·23	1·05	0·08
Bannu	..	..	0·20	0·17	..	..
Punjab :						
Rawalpindi	0·10	..	0·06	0·27	0·73	..
Gujrat	0·10	..	0·70	0·20	0·30	..
Lahore	..	..	0·44	0·18	0·06	..
Ferozepore	..	..	0·70	0·17	0·02	..
Jullundur	..	..	0·40	0·36	..	..
Hissar	..	..	0·70	0·36	..	..
United Provinces :						
Saharanpur	..	..	..	1·03	..	..

Winter-Spring rainfall was evidently in great defeet all over the Iran—India winter rain areas.

II. *Monsoon Rainfall* 1892 *(in inches)*

1892	May	June	July	August	September
Sind :					
Karach	..	..	10·94	0·57	0·07
Mithi	2·00	..	7·43	1·90	2·70
Umarkot	0·99	0·37	4·47	3·74	2·31
Nagar Parkar	4·58	0·08	10·93	5·57	7·91
Rajputana :					
Barmeri	2·23	0·74	5·14	5·47	5·90
Jodhpur	0·93	0·50	4·31	6·14	5·28
Jaisalmer	0·33	0·47	5·89	3·16	0·17
Bikaner	0·09	3·01	7·27	2·96	3·45
Jaipur	0·81	3·79	13·96	21·83	12·06
Ajmer	0·40	0·68	5·08	7·09	6·36
Punjab :					
Rawalpindi	1·03	2·87	5·63	12·67	0·07
Gujrat	1·00	0·20	11·83	14·20	1·00
Lahore	0·72	0·99	8·11	11·68	0·53
Ferozepore	0·85	0·20	10·22	8·74	2·22
Jullundur	0·80	0·08	8·78	9·50	6·62
Hissar	0·09	0·13	9·24	10·04	5·69
N.W.F. Province :					
Peshawar	0·50	0·42	3·68	17·75	0·07
Bannu	..	0·65	8·29	3·60	0·21
United Provinces :					
Saharanpur	0·07	1·16	3·95	22·92	7·90

The pre-monsoon rains in May and June were poor except in a few places. Rainfall in July was fairly heavy throughout North-West India; in August also rains were heavy, especially in many parts of the Punjab; and in September, there was good rainfall in the southern parts of the desert, but little in most other parts.

B. Locust Data 1892.

I. *Winter* 1891-92 (December 1891 to February 1892).

Except for a few flights reported in December in parts of the Punjab, there are no records of locust swarms during December, January and February in any part of north-west India.

There are no data for Persia or Oman too, but as western flights commenced very early in Sind and the Punjab, it is evident that there should have been a large number of overwintering locusts and possibly also some light breeding, in parts of southern Iran or in Oman in January and February.

II. *Spring* 1892 (March to May 1892).

There were no locusts anywhere at the beginning of March.

Western flights. Towards the end of March, locusts first appeared in Sind and Thul in Upper Sind Frontier during week ending 29-III-92. At about the same time winged locusts are said to have made their appearance in Tank and Kulachi Tahsils in Dera Ismail Khan district.

During April in *Sind,* large flights appeared in the Upper Sind Frontier at Thul and Shadadkot and in Shikarpur district and during May, numerous swarms were reported from all parts of Sind, Karachi (Manjhand, Sehwan); Shikarpur (2 talukas); Hyderabad (one taluka); Upper Sind Frontier (Jacobabad, Thul and Shadadkot); Tharparkar (Khipro, Sanghar 15-16/V and Nagar Parkar 20/V).

In the *Punjab,* swarms appeared in April in Shahpur, Jhelum, Hazara, Kohat Peshawar (said to have come from the direction of Kohat Pass), Bannu, Dera Ismail Khan (swarm said to consist of 'young' locusts), Multan (reported to be locusts of young brood) and Karnal. In *May,* swarms were reported from Hoshiarpur, Sialkot, Jhelum, Dera Ismail Khan and Simla.

Presumably by reason of a rainless dry spring, some of the swarms would appear to have covered long distances within a comparatively short time; for one swarm reached as far east as the Manbhum district of Bihar in April and passed off flying from south to north-east. In May, other swarms appeared at Colgong and Banka in Bhagalpur district flying east to west, causing considerable damage to indigo.

Apparently these swarms had passed through the United Provinces and Central India and Central Provinces without being reported, though the appearance of swarms in Dholpur and Alwar States during week ending 10th May is on record.

Spring Breeding. There was no spring breeding anywhere on account of the lack of spring rains.

III. *Summer* 1892 (June to August 1892).

Summer flights. The flights noted in spring continued in June and July. In Bihar, a swarm appeared in June in Manbhum district and flew towards south-west, and another in Madhupur area in north Bhagalpur on the 27th June flying east to west. In the *United Provinces,* damage to sugarcane by locusts was reported from Benaras district during the first week of July. Apparently in these cases, the direction of flight would appear to have been east to west under the influence of the Bay monsoon current, and gradually all the swarms in Bihar and the United Provinces had drifted into Punjab by August.

Summer Breeding.

There was heavy rainfall almost all over north-west India during July, August and September, and conditions were favourable for breeding in most places.

In the Thar area of *Sind*, breeding is not recorded but had doubtless occurred. Presence of hoppers in the Kashmor taluka of Upper Sind Frontier was reported in September, and they were said to be marching down from the hills.

In *Rajputana*, there are no records of flights except for Jaisalmer. Heavy breeding is said to have occurred in Bikaner in the Mirzawala Nizamat, and light breeding at Nokh in Jaisalmer. It is probable that similar breeding had taken place in parts of Marwar also.

In the *Punjab* breeding was reported in September from Bannu district (Mianwali tahsil), Jhelum, (4 tahsils), Rawalpindi (Pindigheb and Gujarkhan), Shahpur, Dera Ismail Khan (Bhakkar and Leiah tahsil), Dera Ghazi Khan (Jampur and Rajanpur tahsils) and Ferozepore (Fazilka), and in October from Hisar.

IV. *Autumn* EBFT. (September to November 1892).

Breeding continued till October-November in the Punjab.

Autumn flights. A fair number of flights was reported from various districts of the *Punjab* during autumn months.

Sind. Numerous swarms were observed in all parts of Sind during the autumn months and also in December. Damage to grass in Kohistan as well as slight damage to crops in other parts was reported.

Rajputana. Autumn crops are said to have suffered from excessive rain in parts of Ajmer-Merwara and five of the Rajputana States: probably locust breeding had also been adversely affected by excessive soil moisture.

United Provinces. Swarms appeared in December in parts of the Fyzabad, Saharanpur and Meerut districts.

Bihar. A swarm is reported to have appeared in Manbhum district travelling north to south-west in *September*.

Summary of Events in 1892:

(1) There were no over-wintered swarms within Indian limits.

(2) Winter-spring rainfall was very scanty in the winter rain areas. There was no spring breeding in the Punjab, and presumably none in the Baluchistan areas.

(3) Flights of locusts—comprised probably of overwintered locusts from Iran and Oman and possibly also partly of fresh adults of a winter brood in Arabia, entered Sind and Punjab at the end of March and during April and May, and continued their flights in N.W. India over Rajputana, the United Provinces, etc., up to Bihar.

(4) The monsoon rainfall was fairly heavy and widespread, and summer breeding occurred in 8 districts of the Punjab, in Bikaner and parts of Jaisalmer and possibly also in Marwar and Thar. Some breeding occurred also in Upper Sind Frontier.

(5) Autumn flights were fairly numerous in Sind and Punjab, but there was very little of eastward autumn migration.

YEAR 1892

A. Weather Notes 1892

I. *Winter-Spring Rainfall* 1891-1892 (*in inches*)

1892-93	Nov.	Dec.	Jan.	Feb.	March	April
Iran :						
Bushire . . .	3·40	1·97	2·86	1·49	1·39	0·12
Jask . . .	..	1·47	0·47	1·72	0·61	..
Baluchistan :						
Quetta . . .	0·06	3·36	3·61	7·53	0·75	1·59
Kalat . . .	..	1·78	2·44	5·11	0·11	0·82
Sind :						
Karachi . . .	..	..	1·27	2·94	..	0·05
Shikarpur . . .	..	0·29	0·20	1·48	..	0·70
Punjab :						
Rawalpindi . .	0·01	2·71	6·62	4·44	1·22	2·98
Gujrat . . .	..	0·90	6·90	1·44	1·94	0·66
Lahore . . .	..	0·80	2·01	3·13	0·64	0·49
Ferozepore . . .	..	1·04	2·04	3·09	0·08	0·58
Jullundur . . .	..	1·75	3·55	2·53	0·43	0·66
Hissar . . .	..	0·21	2·43	0·87	0·57	..
D. G. Khan . .	..	0·51	1·40	1·46	0·06	0·70
N.W.F.Province :						
Peshawar . . .	0·12	0·37	3·17	0·71	2·23	0·79
Bannu . . .	..	0·14	1·24	0·63	1·01	0·86
United Provinces :						
Saharanpur . .	..	1·00	3·67	3·90	1·10	5·50

The winter rainfall was moderate but fairly well spread in the western winter rain areas. Rainfall was rather heavy in the uplands of Baluchistan and in the Punjab especially in December, January and February.

II.—*Monsoon Rainfall* 1893 (*in inches*)

1893	May	June	July	August	September
Sind :					
Karachi	..	6·50	0·76	0·85	..
Mithi	0·16	4·21	7·79	0·85	3·29
Umerkot	..	2·13	4·78	0·14	3·08
Rajputana :					
Barmer	0·42	5·19	6·35	2·90	10·75
Jodhpur	0·64	2·46	8·56	8·56	5·70
Jaisalmer	0·28	2·07	7·53	2·21	1·27
Bikaner	0·93	1·06	4·44	3·10	1·15
Jaipur	0·80	3·36	10·30	6·08	4·57
Ajmer	0·45	4·19	8·40	8·21	7·15
Punjab :					
Rawalpindi	3·79	5·10	20·65	4·85	6·35
Gujrat	0·11	4·35	16·14	4·25	2·70
Lahore	1·90	2·70	7·36	0·50	6·85
Ferozepore	0·74	1·96	8·53	1·27	6·42
Jullundur	3·57	6·29	8·40	2·86	18·57
Hissar	1·66	0·65	9·30	0·10	4·39
N.W.F. Province :					
Peshawar	0·69	0·06	6·89	0·31	1·23
Bannu	1·89	2·17	5·74	0·24	1·83
United Provinces :					
Saharanpur	1·02	6·59	8·69	11·38	10·14

The monsoon began early in June with fairly good falls in many places, and heavy and widespread rain fell in July; in August, rainfall was light in the Thar area and in parts of the desert, but fairly heavy in parts of Punjab; and there was fairly good rainfall with heavy rains in the Punjab and in south Marwar in September. On the whole, precipitation during the monsoon was much in excess of the average.

B.—Locust Data 1893.

I. *Winter* 1892-1893 (December 1892 to February 1893).

Sind. There were fair numbers of swarms which were present in all the districts of Sind in January and the first week of February, during which period they were apparently gradually moving out of Sind into Baluchistan.

Punjab. In January, locusts were seen at Shorkot in Jhang district and also near Ambala.

No locusts were present in the winter months in any other parts of N.W. India.

II. *Spring* 1893 (March to May 1893).

Punjab. During *April*, locusts were reported from Karnal, Ferozepore and Ambala presumably all over-wintered forms. Eggs would appear to have been laid in Karnal district, which hatched early in May.

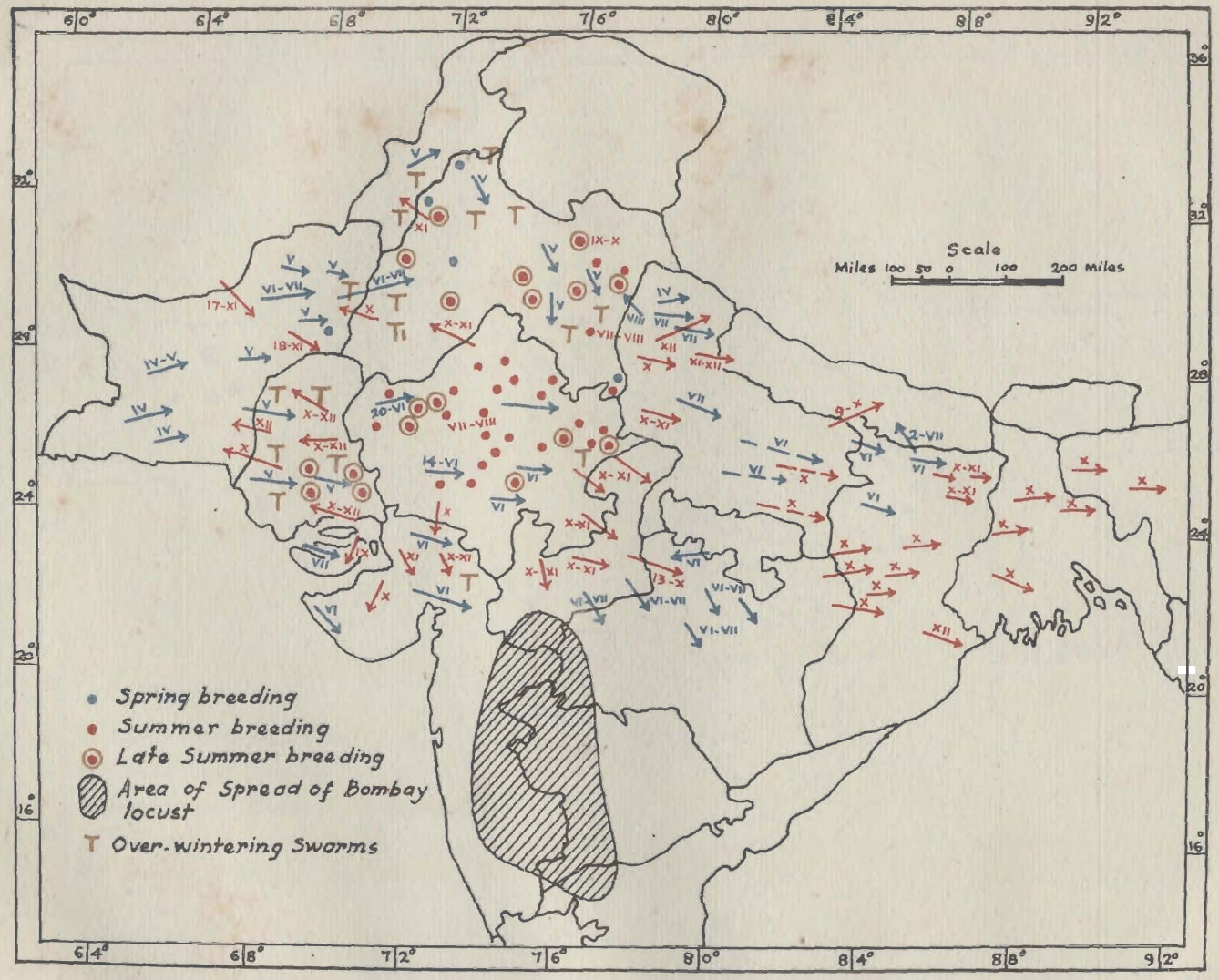


FIG. I LOCUST SITUATION IN INDIA IN 1906

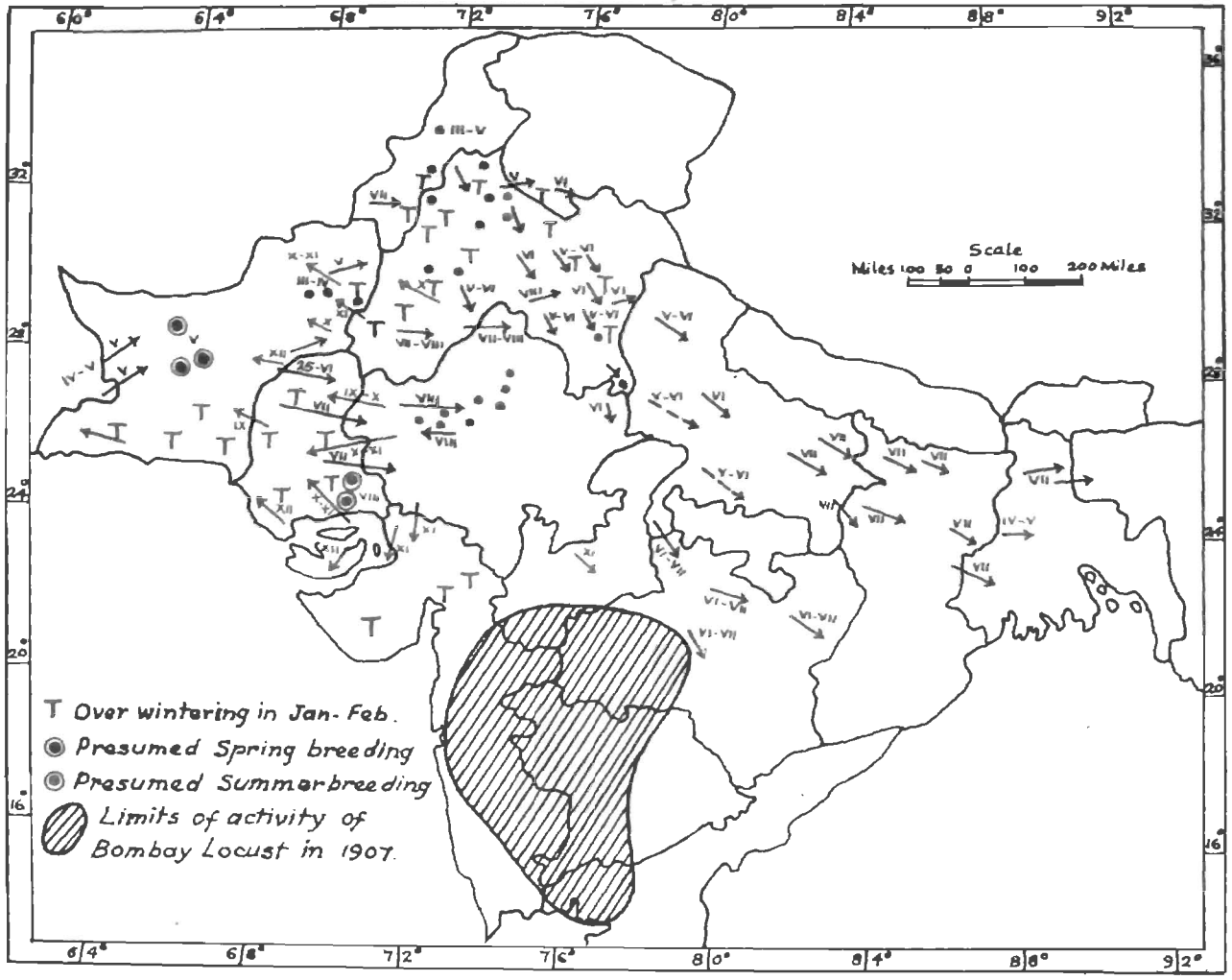


FIG. 2 LOCUST SITUATION IN 1907

Early in May, a flight of locusts from the west alighted in Leiah tahsil in Dera Ismail Khan district (in the first week of May) and departed towards the east. During the succeeding week of May other flights appeared in Gujrat (20-V), Gujranwala, Jhelum and Shahpur, in north Punjab, in Peshawar, Bannu and Dera Ismail Khan in North West Frontier, in Hissar, Rohtak, Ferozepore, Karnal and Gurgaon (20-V) in the south-east, in Jhang, Muzaffargarh and Dera Ghazi Khan in the south-west and Ludhiana and Montgomery in the central Punjab.

Sind. Towards the end of April, (week ending 2nd May 1893), locust swarms first appeared in Sind, in the Upper Sind Frontier and Shikarpur districts. During the succeeding weeks several other swarms were reported from all parts of Sind, flights occurring in Thar Parkar district only during the last week of May.

Rajputana. In Jaisalmer, the first report was that of the 16th May, when swarms appeared from Sind and passed on to Devikot and thence on to Sankra in Marwar the next day. Other swarms were seen at Mayajlar and Lakha during May. There were presumably similar movements of swarms in Marwar and Bikaner in May, reaching the eastern parts of Rajputana.

United Provinces. Some of these flights reached the Saharanpur tahsil during the 1st week of May, and others flew over the province during the succeeding weeks till by the last week of May, their presence was reported from Banda, Agra, Jhansi and Meerut districts.

Central Provinces. On the 24th May locusts were reported to have passed over Chhindwara passing from north-east to south-west and again on the 30th. A swarm was observed at Lalbara in Balaghat on the 25th May coming from the west from Seoni. On the 29th a flight was seen at Armori in Chanda district. During the last week of May, locusts were reported to have appeared in Saugor, Chhindwara, Bhandara, Balaghat, Chanda and Seoni districts. During this period, the general trend of movements in the Central Provinces, is seen to have been north to south. A study of the daily weather data of this period would show that from the 20th May a depression had appeared off the Circars Coast and developed by the 24th into a cyclonic storm which persisted till the 28th, and that this had induced a northerly air in Central Provinces.

All these swarm movements would indicate that an immigration of swarms generated in the western winter-rain areas in Baluchistan, Iran and East Arabia had taken place from the beginning of May and had reached as far east as Banda district in the United Provinces and as far south as the Chanda district of Central Provinces.

Spring breeding. As the rainfall in the spring months was favourable for breeding, oviposition would appear to have taken place in the Punjab in Karnal district and in Saharanpur district in the United Provinces during April.

During *May*, further reports of breeding were received from Bannu, Gujrat, Hoshiarpur, Shahpur, Jhelum, Muzaffargarh and Karnal.

Baluchistan.—According to the progress report of the Baluchistan Forest Department for 1892-93, locusts appeared on the Shebo plantation on the 14th May and laid eggs. Between the 22nd and 28th June, young locusts attacked the plantation and were disposed off by beating, burning etc.

III. *Summer* 1893 (June to August 1893).

Spring breeding. Hoppers from the eggs laid in May in Punjab were being found during June and measures were taken for their destruction.

Summer flights. The flights reported in May continued in June and July.

United Provinces. Flights were reported during June from parts of Benares, Balia, Cawnpore, Fyzabad, Rai Bareli and Almora districts. By the middle of June, however, movements of swarms had presumably been affected by easterly winds and they were apparently heading westwards so that, by the end of July, few flights were to be seen in the Province except in Almora.

Bengal and Bihar. Swarms were reported from *Bengal* in Burdwan in June and from *Bihar* in Gaya (3 flights in 2nd week of June), in Saran (15-16 June), and in Shahabad, Patna and Gaya districts (in third week of June). It is reported that all these swarms were ultimately swept into the United Provinces and thence westwards into the Punjab.

Central Provinces. A flights appeared in Jubbulpore district during the 1st week of June.

There is mention in the annual Report of the Operations of the Department of Land Records and Agriculture in Madras for 1893-94 that in July-August 1893, locusts or grasshoppers appeared in a few villages of Kurnool and Bellary in *Madras* but did only slight damage and soon disappeared. From the data available for Central Provinces in May, locust swarms would appear to have reached as far south as Chanda district by the 29th May, under the influence of the northerly winds that prevailed during the latter half of May. It may perhaps be presumed that some of the flights had spread into the districts of Hyderabad and that some had strayed further south into the areas of Kurnool and Bellary helped by the northerly wind circulation that developed in these parts between the 13th and the 18th June in connection with the passage of a cyclonic storm from the Circars Coast.

Summer breeding: Sind. There was heavy rainfall in June and July in the Thar area of Thar-Parkar district. Locusts are said to have appeared in three taluks of Thar and to have laid eggs in July. Locusts also appeared in Shikarpur and Upper Sind Frontier in July and the first week of August. After a break in August, further heavy rainfall followed in September, but there is no mention of locusts after the 2nd week of August.

Rajputana. There are records about locusts only for the Jaisalmer State. Numerous swarms were apparently roaming about this area, migrating from Jaisalmer into Sind, Bahawalpur and Marwar and back again during June, July and August. Following good rainfall in June and July, egglaying occurred in July and August in parts of the state, as in Tanot and Nokh, and hoppers emerged which were destroyed. Apparently similar breeding had taken place in other parts of the Rajputana desert area, but there are no records. Curious to note, there is no recorded information about autumn flights after the 15th September for Jaisalmer also.

Punjab. Though there were large numbers of locusts in June and July, there is no mention of locusts in the season and crop reports from August onwards. Perhaps on account of the very heavy and almost continuous rainfall from June to September in many parts of the Province, locust breeding had apparently been adversely affected and the swarms perhaps killed out by the excessive moisture.

IV. *Autumn* 1893. (September to November 1893).

There are no data in regard to the activities of locusts anywhere in N.W. India for the autumn months after the middle of September.

Summary of Events in 1893.

(1) The winter-spring rainfall was fairly good in the winter rain areas of N.W. India and Iran. Rains were particularly good in the uplands of Baluchistan and in the Punjab.

(2) Small numbers of overwintered swarms occurred in parts of Punjab and Sind. Some of these bred in Karnal in the Punjab in April.

(3) There is very little information about the situation in spring in Baluchistan, but in view of the good rainfall in the interior, breeding had probably occurred in Chagai, Mekran and the uplands of Baluchistan, as had happened for instance in the Shebo Forest plantation in Thal-Chotiali in May to June. It is quite likely that good spring breeding had occurred in the Persian and Oman areas.

(4) Migration of swarms from the west commenced very early, *i.e.* by the end of April, and spread into Sind, Rajputana and the Punjab during May. Spring breeding occurred in several districts of the Punjab and in Saharanpur district in the United Provinces.

(5) By the latter half of May, swarms had penetrated into the United Provinces, Central Provinces and parts of Bihar. In June, flights occurred in several places of Bihar and also in Burdwan in Bengal. During July, most of these eastern flights had been swept westward into United Provinces and Punjab.

(6) By the end of May, locust swarms had entered Chanda district of Central Provinces, and it is surmised that, under the influence of northerly winds, they had entered the Hyderabad state and thence filtered into Kurnool and Bellary by July (as per reports).

(7) Summer breeding is known to have occurred in the Thar area of Sind and in parts of Jaisalmer, but probably the very heavy rainfall of the monsoon months had acted prejudicially to the breeding of swarms. In the Punjab, there is no record of breeding.

(8) The autumn of 1893 was marked by a complete absence of swarms in the Indian area. Possibly eggs had been destroyed by excessive soil moisture and the locusts themselves had been killed by the heavy rains. The locusts that survived had possibly reverted to the solitary phase type in reaction to the luxuriant vegetational cover that had sprung up in the desert after heavy rainfall.

YEAR 1894

A.—Weather Notes 1894

I.—*Winter-Spring Rainfall* 1893-1894

1893-1894	November	December	January	February	March	April
Iran :						
Bushire . . .	0·73	10·34	1·12	4·04	1·31	0.13
Jask . . .	..	0·32	2·61	2·07	1.03	0.21
Arabia :						
Muscat . . .	0·02	0·50	0·44	2·24	0·28	0.20
Baluchistan :						
Quetta . . .	..	0·56	3·98	5·80	3·24	1·59
Kalat . . .	..	0·19	2·12	7·48	2·61	0.23

1893-1894	November	December	January	February	March	April
Sind :						
Karachi . . .	0·02	0·67	2·81	0·93	0·02	..
N.W.F. Province :						
Peshawar . . .	..	0·94	1·96	0·94	1·46	2·55
Punjab :						
Rawalpindi . . .	..	0·22	5·46	2·03	3·80	2·03
Ferozepore . . .	..	0·37	3·63	0·35	0·91	0·03
Hissar . . .	..	0·90	2·28	0·15	0·72	..

The winter rainfall was fairly good in the winter rain areas, especially so in the uplands of Baluchistan in the months of January, February and March. Rainfall in the Punjab was somewhat in defect.

II.—*Monsoon Rainfall* 1894

1894	May	June	July	August	September
Sind :					
Karachi	..	..	18·63	..	..
Mithis.	..	4·86	9·31	0·13	1·01
Umarkot	..	3·03	7·76	2·68	0·61
Rajputana :					
Barmer	1·00	2·75	1·18	1·30	1·40
Jodhpur	..	5·74	3·38	1·50	1·92
Jaisalmer	..	1·94	1·89	5·30	0·52
Bikaner	0·03	5·81	1·77	1·48	0·20
Ajmer	0·02	7·27	6·66	3·72	5·79
Punjab :					
Rawalpindi	0·57	2·99	14·38	6·49	3·14
Ferozepure	..	14·76	10·43	1·94	0·94
Hissar	0·35	2·26	1·62	5·80	2·16
N.W.F. Province:					
Peshawar	0·79	..	1·74	0·41	..

Monsoon began early; fairly good and widespread rainfall in June; heavy rainfall in July in the Thar area of Sind and the Punjab, but little rain in other areas; rainfall in defect in August, except in Jaisalmer in parts of Punjab; light rainfall in September on the whole.

B.—LOCUST DATA 1894.

I. *Spring* 1894 (*Dec.* 93—*Feb.* 94).—no data.

II. *Spring* 1894. (*March-May* 1894)—no data.

III. *Summer* 1894.

Summer flights: Sind. The earliest swarms were reported at the end of May (week ending 5th June) at Kakar in Shikarpur damaging mangoes, and at Shadadkot in Upper Sind Frontier. Locusts were noticed in two talukas of Thar-Parkar during the last week of June, and in another taluka about the middle of July, after which there were no locust reports. There was very heavy rain in July, and breeding should have been possible, but there is no information on record.

Rajputana. A large swarm appeared at Nokh from Sind and crossed over to Bap on the 2nd June; and another large flight arrived at Tanot on the 2nd from Bahawalpore and passed on to Bap and Nokh on the 5th. A third was observed on 9th at Bap coming from Bikaner and passing into Marwar. There are no other records for Rajputana. As there was a fair amount of rainfall at places, light breeding should have been possible in Jaisalmer and Marwar. According to a report of the Rajputana Political Agency for the week ending 1st September 1894, 41 maunds of young locusts were destroyed in the Suratgarh tahsil, and 400 maunds in the Mirzawala tahsil between the 29th July and the 4th August 1894. Some hoppers were said to have been similarly destroyed in parts of Sardarshahr, Bhaderan, Rajgarh, Hanumangarh, Ratangarh and Nohar tahsils. This would indicate that there was widespread breeding in the Bikaner State in the wake of heavy rainfall in June (5·81 inches at Bikaner). Possibly similar breeding might have occurred in the adjoining parts of Jodhpur and Jaipur States.

Punjab. The only record of locusts is for Ferozepore in July. This might be correlated with the reports of locust damage in the adjoining parts of the Bikaner State in July-August.

Bihar. Locusts were reported to have appeared in Hazaribagh district (Kodarma Thana) and to have caused some slight injury to the Rice crop (presumably in July).

Bengal. Locusts visited the Tangail sub-division Mymensingh district probably in July.

It is surmised that spring breeding had taken place in parts of Baluchistan and Persia, and that the spring generation of locusts had migrated in May and June into Sind and Rajputana, and that part at least of these flights had passed on to Bihar and Bengal.

IV. *Autumn* 1894.—No information on locusts.

Summary of Events in 1894.

(1) Winter rainfall in Persia and Oman was fairly good especially in February. Spring breeding should have been possible.

(2) Rainfall being similarly satisfactory in Baluchistan, it is surmised that some spring breeding had occurred.

(3) Summer flights composed of the new generation from the winter-rain areas entered Sind and Rajputana early in June; part of the early flights probably reached Bihar and Bengal by July.

(4) Monsoon was fairly heavy in parts of the desert in June and July, and summer breeding occurred in parts of Bikaner and probably also in Jaisalmer and Marwar and Thar, but there were no reports of autumn flights anywhere in North West India. Possibly the breeding was sparse and the progeny had reverted to the solitary phase.

YEAR 1895

A.—Weather Notes 1895.

I.—*Winter-Spring Rainfall* 1894-95 (*in inches*)

1894-1895	November	December	January	February	March	April
Iran :						
Bushire	11·68	7·81	2·40	0·03	0·29	0·23
Jask	2·04	1·40	1·48	1·29	0·88	0·02
Arabia :						
Muscat	..	1·24	4·18	0·62	2·54	..
Baluchistan :						
Quetta	0·11	1·90	1·27	0·25	1·23	0·37
Kalat	..	0·93	3·03	0·23	0·92	..
Sind :						
Karachi	..	0·32	0·24	0·32	0·07	..
N.W.F. Province :						
Peshawar	0·03	0·44	0·08	0·88	7·50	2·02
Bannu	0·04	0·28	0·07	0·09	3·36	0·96
Punjab :						
Rawalpindi	0·09	1·17	2·51	1·42	3·70	1·22
Ambala	3·57	2·27	2·76	0·30	0.20	0·58
Sirsa	..	0·67	1·97	0·23	0·37	0·43

Winter rainfall was fairly good in Persia and Oman. In Oman, rain seems to have been specially heavy in January and March. On the other hand, rainfall in Baluchistan and Punjab was on the whole poor, lower than average. In north Punjab and North West Frontier Province there was heavy rainfall in March and April.

II.—*Monsoon Rainfall* 1854 (*in inches*)

1895	May	June	July	August	September
Sind :					
Karachi	..	0·75	0·13	3·21	..
Mithi	..	1·53	1·17	1·36	..
Chachro	..	0·87	1·14	2·73	..
Rajputana :					
Barmer	0·05	2·20	4·33	2·73	..
Jodhpur	..	..	4·70	6·38	1·28
Jaisalmer	0·19	0·84	0·42	0·43	0·23
Bikaner	..	2·17	1·63	5·20	0·53
Jaipur	0·01	1·82	8·71	10·60	0·27
Punjab :					
Ambala	0·04	13·87	3·75	12·78	..
Rawalpindi	0·09	7·01	2·91	10·40	0·89
Sirsa	..	1·10	2·45	2·80	..
N.W.F. Province :					
Peshawar	0·03	0·40	..	1·84	0·33

Monsoon commenced in June with light rainfall except north Punjab; rainfall was poor in July, but heavier in August; little rainfall in September.

B.—LOCUST DATA 1895.

I. *Winter* 1894-95. (December 1894 to February 1895).

No records.

II. *Spring* 1895. (March to May 1895).

Baluchistan. According to the Changai District Gazetteer, swarms of locusts visited Nushki from the west in the spring of 1895 and caused considerable damage to grazing and young crops.

Western flights. Sind. The first report of locusts in Sind was that of their appearance from the south on the 3rd May in Thul in Upper Sind Frontier from Shikarpur and moving off three days later towards Kachhi. During the succeeding week, flights were observed in Shikarpur and Upper Sind Frontier districts. In June, flights passed over Rato Dero in Shikarpur district.

In the *Punjab* also, the first report of appearance of locusts was in the first week of May at Bhakkar in Dera Ismail Khan passing west to east. Flights were also reported from Multan, Muzaffargarh, Shahpur and Dera Ismail Khan during the succeeding weeks.

Spring breeding. Eggs were laid in Tonk tehsil of Dera Ismail Khan in the third week of May.

III. *Summer* 1895. (June to August, 1895).

Hoppers which appeared in Tonk in Dera Ismail Khan district were destroyed. Presumably hoppers appeared also in Bannu district (Marwat tahsil) during June-July.

There is no information available in regard to Rajputana. Possibly late breeding of the *solitaria* type occurred in Marwar and Bikaner.

IV. *Autumn* 1895.—(September to November 1895).

No information available.

Summary of Events in 1895.

(1) Good winter rainfall in Iran and Oman in December, January and March. In the Indian areas, rains were throughout light, except in March in the North West Frontier Province and North Punjab.

(2) Spring breeding occurred in May in Dera Ismail Khan and Bannu, and probably it occurred in Chagai too.

(3) Flights of locusts bred in Persia and Oman entered Sind and the North West Frontier Province in the first week of May and probably entered Rajputana at about the same time.

(4) Monsoon was defective in the desert, but probably some breeding took place in parts of Marwar and Bikaner.

(5) No records of autumn flights.

CHAPTER II

SUB-PERIOD 1896—1899

YEAR 1896

A.—WEATHER NOTES 1896

I.—*Winter-Spring Rainfall* 1894-95 *(in inches)*

1895-1896	November	December	January	February	March	April
Iran :						
Bushire	0·42	0·12	2·64	0·02	1·05	0·18
Jask	0·04	..	0·88	0·25	2·20	..
Arabia :						
Muscat	0·70	..	2·47	0·14	1·54	..
Baluchistan :						
Quetta	0·57	1·86	1·68	1·85	2·19	0·14
Chaman	0·30	1·07	1·04	1·31	1·22	0·16
Sind :						
Karachi	..	0·13	..	0·01	..	..
N.W.F. Province :						
Peshawar . . .	0·16	..	0·98	2·44	1·25	0·26
Punjab :						
Rawalpindi . . .	0·04	..	2·34	1·09	1·40	0·23
Gujarat	..	..	..	0·57	0·70	0·20
Jullundur . . .	..	..	0·46	1·70	..	..
Hissar	..	..	..	0·22	..	..

Winter-spring rainfall in Iran and Oman fairly satisfactory in January and March, but in Baluchistan and Punjab more or less in defect.

II.—*Monsoon—Rainfall* 1896 (*in inches*)

1896	May	June	July	August	September
Baluchistan :					
Quetta	0·04	1·14	0·02	1·36	..
Kalat	..	2·41	0·28	1·30	..
Sind :					
Karachi	..	7·30	0·06	4·51	..
Mithi	..	4·38	1·76	1·46	..
Chachro	..	4·70	2·13	1·57	..
Rajputana :					
Barmer	..	2·43	2·43	5·51	..
Jodhpur	..	3·88	3·83	4·24	..
Jaisalmer	..	0·64	1·85	1·11	..
Devikot	..	2·70	0·80	2·99	..
Bap	..	1·73	2·54	0·50	..
Jaipur	0·88	2·48	3·22	5·60	0·15
Bikaner	0·15	1·62	4·35	0·97	..
Ajmer	0·23	5·66	9·85	8·44	0·41
Punjab :					
Rawalpindi	0·45	3·00	5·28	9·55	1·64
Ferozepore	0·03	0·47	0·48	0·30	0·620
Jullundur	0·06	5·60	2·06	7·80	..
Hissar	0·85	0·22	1·81	1·45	0·59
N. W. F. Provinces :					
Peshawar	0·50	..	0·55	0·10	..
United Provinces :					
Muttra	0·10	1·62	9·09	1·80	0·07

The monsoon began early: there was fairly good rainfall in June in Thar and in Rajputana generally; a fair amount was registered in July in Rajputana, but little in Thar and south-east Punjab; there were fairly good falls in August in the desert and in Punjab generally; little rain in September. The monsoon apparently extended its influence into eastern Baluchistan in June and August.

B.—Locust Data 1896.

I. *Winter* 1895-1896. (December 1895 to February 1896).

No records.

II. *Spring* 1896. (March to May 1896).

No records.

III. *Summer* 1896. (June to August 1896).

Summer flights.—Sind. No Locusts were present in N.W. India till the middle of June, but in the third week, swarms appeared suddenly in Shikarpur (Kakar and Nasirabad) and Hyderabad (Moro). Next week they were sighted at Karachi, Manjhand and Sehwan in Karachi district. Swarms appeared at Sanghar in Thar Parkar in the first week of July. Numerous flights were passing over Sind during July and August.

Rajputana. The first record of swarms in Rajputana was on the 26th June at Shahgarh in Jaisalmer, locusts of yellow colour arriving from Sind passed on towards Sam Pargana. During July and August, numerous swarms were active in Jaisalmer passing from Sind and Bahawalpore into Marwar and Bikaner.

Punjab. Swarms appeared in Gurgaon, Hissar, Rohtak and Karnal during the early part of July. They also visited Rawalpindi flying east to west in Pindi-gheb tehsil and Bannu and Dera Ismail Khan during the latter part of July. Further flights occurred during August in the above districts as also in Ludhiana and Amritsar.

Bihar. In the annual report of the Department of Land Revenue and Agriculture, Bengal for year ending the 31st March 1898, it is stated that locusts were observed in Gaya, Champaran and Muzaffarpur districts during the rainy season of 1896-97. If so, before reaching Bihar, the swarms should have traversed parts of the United Provinces and Central India in June and July 1896.

Summer breeding.—Sind. As a result of good rainfall in July, breeding occurred in the Desert tahsils of the Thar-Parkar district.

Rajputana. There are records only for Jaisalmer in Rajputana. According to the Dewan of Jaisalmer, oviposition and hatching occurred in Bap and Nokh in the east, in Tanot and Kishengarh in the north, in Jaisalmer in the centre, and in Devikot, Khuiala and Sam Khaba in the south of the State. This would indicate that breeding had been widespread over the Jaisalmer State. As fairly good rain-fall had occurred in parts of Marwar and Bikaner also, there is little reason to think that extensive breeding had not taken place all over the desert areas of west Rajputana.

Punjab.—Available data show that breeding had taken place in the Rohtak district (Jhajjar) and in Jind State. Though probably oviposition had occurred in other districts like Karnal and Delhi, there are no records.

Baluchistan.—As heavy rain had fallen in June and August in the Karachi district, it is possible that rainfall had, as usual, extended into the adjoining areas of Lasbela also at these periods and given rise to light breeding.

IV. *Autumn* 1896. (September to November 1896).

Breeding. Hoppers were found till the end of September in Jaisalmer.

Autumn flights.—Sind. Numerous flights of pink locusts produced in the Rajputana and Thar area, were reported during the months of September, October, November and December from all parts of Sind, causing damage to standing crops and to gardens and trees in general.

Rajputana. From the records available, a great many flights of pink coloured locusts were apparently active in Jaisalmer and Sirohi during the autumn months and in December. The general direction of flight was east to west or north to south. Swarms were also reported from Bhurtpore in December. Though there are no definite records, such flights should doubtless have been observable all over Rajputana, as this was apparently the breeding area from which the large flights reported from Sind, Punjab, United Provinces, Bihar, Bengal and Bombay during autumn had radiated.

Punjab. There are several reports of flights in September in Gurgaon, Delhi, Karnal. Rohtak and Ferozepore in the east and in Gujaranwala, Lahore, Montgomery, Jhang, Amritsar, Dera Ismail Khan and Dera Ghazi Khan in the west. In October and November, flights occurred in most of

the above districts and also in Muzaffargarh, Multan and Simla (October). In December, swarms were observed mostly in the western districts: Jhang, Dera Ismail Khan and Muzaffargarh.

United Provinces. The first flight of the autumn season passed over Muttra and Etawah, during the first week of September and by the end of the month swarms had spread over the greater part of the Province up to Ghazipur in the east. There were several reports during October, but by November, swarms had become few and were reported only from Mirzapur and two other districts; and in December, only from Almora.

Bihar. Flights appeared in October and November in various parts of Bihar. Swarms were reported from Shahabad, Patna, Saran and Bhagalpur districts in the north and from Palamau, Hazaribagh and Manbhum districts in the Chota Nagpur division, and are said to have damaged various autumn and rabi crops.

Bengal. The earliest report of occurrence of a swarm in Bengal was in the second week of September from the Dinajpur district. Apparently this belonged so a part of the summer flights that are said to have reached the Gaya, Champaran and Muzaffarpur districts of Bihar during the rainy season (July to August).

The main autumn flights were reported in October from Bankura and Rajshahi districts, and in November to December from many districts, 24—Parganas, Nadia, Malda, Murshidabad, Khulna, Midnapore and Dacca (Narainganj). They also reached as far north as Dinajpur and Rangpur districts and the Sikkim State during November-December.

Bombay Presidency. (Western India States). Towards the close of October locust swarms appeared in the Mahikantha Agency, the Mehsana district of Baroda and a week later, in the Ahmedabad and Kaira districts. Towards the middle of November, locusts were reported from the Rajkot area of Kathiawar.

These swarms had apparently been derived from Marwar-Sirohi areas and had passed south under the guidance of the northerly winds that often develop in these areas during the autumn months.

Summery of Events in 1896.

(1) The winter-spring rainfall in south Persia and East Arabia was fairly satisfactory especially in January and March, and it is probable that good breeding had taken place in spring in these areas.

(2) In British Baluchistan and in the Punjab, rainfall was in defect. Conditions were apparently not favourable for locust multiplication in Baluchistan.

(3) Migrants from the west arrived in Sind and Jaisalmer by the middle of June and after passing over Rajputana and Central India reached Bihar by July.

(4) The monsoon was early and good rain fell in June, as also in July and August in many places in the desert. There was fairly widespread breeding in Jaisalmer and possibly also in Marwar and Thar. Some breeding probably took place also in Bikaner and east Punjab.

(5) As a result of heavy multiplication, large numbers of swarms were evidently produced, some of which were found flying in the autumn months in a westerly direction in Sind, west Rajputana and Punjab, others flying eastwards into United Provinces, Bihar and Bengal up to Dacca and Sikkim; and some flying south into North Gujarat (Mahikantha, Ahmedabad and Kaira) and Kathiawar.

YEAR 1897

A.—Weather Notes 1897

I.—*Winter-Spring Rainfall* 1896-97 (*in inches*)

1896-1897	November	December	January	February	March	April
Iran :						
Bushire	0·74	..	4·41	1·21	0·31	0·06
Jask	0·43	..	0·53	1·14	0·12	..
Ispahan	0·61	..	0·34	0·11	1·97	0·14
Meshed	0·66	0·02	1·15	0·21	1·92	3·27
East Arabia :						
Muscat	3·04	..	0·50	0·63	0·03	..
Baluchistan :						
Quetta	0·94	..	2·68	1·68	1·37	2·28
Pishin	1·64	..	3·27	2·29	1·49	2·28
Chaman	1·94	..	4·59	2·75	0·99	1·48
Sind :						
Karachi	..	..	0·10	0·17	..	..
N.W.F. Province :						
Peshawar	1·06	..	3·23	1·14	2·06	2·72
Bannu	0·79	..	1·92	1·10	2·04	3·31
Punjab :						
Rawalpindi	0·95	0·14	2·55	1·16	3·18	1·76
Gujrat	0·10	0·20	1·70	0·60	1·47	0·95
Jullundur	0·06	0·36	1·18	0·98	1·29	1·97
Hissar	0·33	0·17	0·15	..	0·07	0·25

Winter rainfall rather poor in south Iran and Oman, except in November in Oman (3·04 in., at Muscat). Good rainfall in Upper Baluchistan and in north Punjab and the Frontier from January to April.

II.—*Monsoon Rainfall* 1897 (*in inches*)

1897	May	June	July	August	September
Baluchistan :					
Quetta	0·04	0.32	..	..	..
Kalat	0·03	..	0·33	..	..
Rindli	..	..	1·10	4·14	..
Sibi	..	0.26	0·68	4·88	0·22
Sind :					
Karachi	..	..	3·77	6·44	1.59
Jacobabad	..	0·04	1·16	2·45	0.39
Mithi	..	0·50	4·14	9·21	1.93
Chachro	..	0·27	2·07	10·70	0.85

1897	May	June	July	August	September
Rajputana :					
Barmer	..	..	2·47	0·25	1·17
Jodhpur	..	0·10	2·90	8·25	2·22
Jaisalmer	..	0·18	2·11	5·28	2·49
Bikaner	0·12	0·11	5·29	10·51	0·48
Jaipur	0·66	0·25	5·85	7·32	1·86
Ajmer	0·27	0·17	8·03	12·39	1·05
Punjab :					
Rawalpindi	1·06	0·74	8·48	9·00	1·78
Gujrat	..	0·98	1·24	5·13	1·20
Jullundur	0·32	0·64	7·62	7·79	0·71
D.G. Khan	0·19	0·46	1·27	1·46	..
Hissar	0·08	1·33	3·22	13·20	4·95
N.W.F. Province :					
Peshawar	1·44	0·47	0·54	4·76	0·41
Bannu	0·49	0·21	3·58	6·13	0·60

The monsoon began late, but there was fairly heavy and widespread rainfall in most parts of North-West India in July and August and a fair amount of rainfall in September. The monsoon did not extend into Baluchistan, but affected Kachhi and possibly Lasbela.

B.—Locust Data 1897.

I. *Winter* 1896-97. (December 1896 to February 1897).

There is no information available for Baluchistan for this period. In the Punjab, a few swarms were reported from the Dera Ismail Khan, Jhang and Muzaffargarh districts in the early part of December, but none in January and February except for a single flight at Kulachi in Dera Ismail Khan district in second week of February. In Sind, swarms were reported to have been active in Upper Sind Frontier, Shikarpur and Karachi districts in January, but in February there were no reports except for a few from Karachi district. There was a solitary report in mid-January from the Almora district in the United Provinces. Thus, there seems to have been, on the whole, not much of overwintering in north-west India.

II. *Spring* 1897. (March to May 1897).

Spring breeding.—Baluchistan. It is only in 1897 that fairly full information regarding the activities of locusts in Baluchistan is for the first time available, thanks to the extracts from the Baluchistan Agency Diaries published in the Indian Museum Notes (I.M.N. IV. No. 4, 1900), and some data were also obtainable from the files of the Quetta-Pishin Agency. It would appear that swarms arrived in the Pishin area about the end of March or the beginning of April and laid eggs in various parts of Pishin tahsil. Large numbers of crawling bands of hoppers appeared in May in these places, as also in Chaman and Shorarud areas. Webb-Ware reported that Nushki (Chagai district) was at this time swarming with young locusts. From the diaries of the Political Assistant, Chaman, it would appear that, in Afghanistan, the cultivated areas of Kadanai, Salessun, Maruf, Arghastan and Tarnak stretching from the Chaman borders up to Kandahar had also been severely infested in 1897. Breeding was reported also from the Hindubagh and Fort Sandeman tahsils of Zhob.

While the hoppers in these areas were assuming the adult stage by the end of May or the beginning of June, the young locusts hatched out at higher elevations on the Toba Achakzai and Toba Kakari Ranges were still present in myriads till the end of June and caused heavy damage to wheat and barley crops, as also to fruit trees and grass. Hoppers were said to be in such dense swarms on the hillsides that the train from Quetta to Chaman was delayed 2½ hours on this account on the 12th June.

Punjab and North West Frontier. There are no records of flights in the Punjab for March and the early half of April. The first record of a swarm is for the third week of April in Dera Ismail Khan. Other flights subsequently appeared in April in Marwar tahsil of Bannu, in Dera Ismail Khan district and in Shorkot tahsil of Jhang. These swarms—which evidently came from the west spread over the northern parts, and as a result of favourable spring rainfall, laid eggs in various districts: Rawalpindi, Dera Ismail Khan, Jhelum, Kohat and Bannu during May. Hoppers were reported damaging crops in June and necessary steps were taken for their destruction.

These early flights—which appeared in March-April in Baluchistan, Punjab and N.W. Frontier—were presumably those of overwintered yellow locusts from Persian and Arabian areas, and in view of the poor rainfall in winter and spring in southern Iran, it should be considered probable that the prevailing drought in spring in the south had accelerated the movements of the yellow swarms and brought them to the upland areas of Iran, Afghanistan and Baluchistan by March—much earlier than usual, as had been noted under similar conditions in 1929.

Summer flights.

Sind. Swarm movements are on record for the month of March and the first week of April in south Sind (Karachi and Hyderabad), but there are no further reports till the middle of May. These were evidently overwintered locusts which apparently passed gradually into Baluchistan during March and April.

The western flights first appeared in Sind during the week ending the 18th May in Karachi (Dadu), Hyderabad (Moro) and Shikarpur (Kakar). Numerous other flights were subsequently reported all over Sind, coming generally from the western direction during May, June and July.

Some of these flights would appear to have passed over parts of Baluchistan during the summer months, as for instance in Zhob, Quetta-Pishin and Thal-Chotiali districts and were evidently derived from areas of spring breeding in Afghanistan and north Persia.

According to a report of the Political Agent, Bushire, large swarms of pink locusts were present during the early part of June around Shiraz in Persia, where they were destroying wheat and barley crops and vegetables [I.M.N. IV No. 4, 1900].

Punjab. The western flights appeared in May and had reached as far east as Ambala and Gurgaon by the middle of the month. They were also reported about the same time in Shahpur, Rawalpindi and Dera Ismail Khan districts. Subsequently they would appear to have spread over the greater part of the Province.

Rajputana. The earliest record for Rajputana is from Jaisalmer (18th May). During the latter half of May, several flights were reported coming from Sind, from the west or from Marwar from south and passing eastwards or north-eastwards into Marwar and Bikaner. Owing to the

prevailing drought in May and June, these flights would appear to have passed rapidly across Rajputana into the Punjab, the United Provinces and Central India.

III. *Summer* 1897. (June to August 1897).

Spring breeding. As already mentioned, breeding continued in June in the upland areas of Baluchistan, as for instance in the Pishin, Chaman and Chagai areas and in Hindubagh and Fort Sandeman Tahsils; and on the high Toba Ranges (Toba Achakzai and Toba Kakari), hopper infestation extended even into mid-July.

In the Punjab, late spring breeding continued in June in the northern districts (Bannu, Kohat, Dera Ismail Khan, Rawalpindi and Jhelum).

Summer flights.—The flights from the western areas, which began about the middle of May in Sind, Punjab and Rajputana, would appear to have rapidly advanced eastwards across Central India and the United Provinces into Bihar. Swarms are reported to have appeared in Palamau district (Bihar) on the 12th, 14th and 15th June, and also in Manbhum district in the course of June, doing considerable damage to *mung*, *kaddu*, maize, *marua*, and *arhar* (Cajanus). During the rainy season of 1897 (presumably June, July and August), flights were said to have appeared in Bhagalpur, Patna (Barh), Saran, Shahabad, Hazaribagh, Palamau and Manbhum districts. According to the season report for week ending 5th July 1897 (Gazette of India), a flight of locusts visited Monghyr, Bhagalpur and Sonthal Parganas on the 4th July. In the Central Provinces, appearance of locusts is recorded in Mungeli tahsil of Bilaspur district during the week ending 5th July.

It is thus seen that summer flights reached as far east Bhagalpur and Santhal Parganas (88°E. Long) during the summer of 1897.

Specially large flights swept across upper Baluchistan in August over Chaman, Ziarat, Zhob, Loralai and Sibi areas in the direction of Punjab, Sind and Rajputana. In the Punjab, there were numerous flights during July and August all over the province.

Summer breeding.—There was apparently no summer breeding anywhere in Baluchistan, but, as there was heavy rainfall in July-August in Kachhi, breeding could have been expected there.

In *Sind*, where there were good falls of rain in July and August in the desert areas, oviposition took place in five taluks of Thar-Parkar district.

In the *Punjab*, as a result of widespread and heavy rainfall all over the province, oviposition occurred in over 16 districts and in the Jind State. Breeding was specially concentrated in the south-eastern districts: Gurgaon, Delhi, Rohtak, Hissar and Karnal.

In *Rajputana*, detailed data are available only for Jaisalmer and Sirohi and to a certain extent for Marwar. In Jaisalmer, in the wake of good rainfall in July-August, widespread egglaying followed and large numbers of young locusts were reported from many parganas in August and September. Similarly, breeding also occurred in the Sirohi State. It is seen from the report of the Political Administration of Rajputana States for 1897-1898 that 'locusts appeared in Marwar in the months of May, July, August and September and did appreciable damage to kharif crops especially in Shergarh, Siwana, Jalor, Pachpadra, Bali and Bilara'. Evidently breeding had occurred almost all over the Jodhpur State and there is little reason to doubt that breeding had also extended into the Bikaner areas.

From the data available in the season reports of the Gazette of India, and from information in the files of the Rajputana Agency, it is apparent that extensive breeding had taken place in many parts of Eastern Rajputana also: Tonk, Haraoti, Shahpura, Bhurtpore, Karauli, Jaipur, Bundi, Kotah, Meywar and Ajmer-Merwara.

Flights would appear to have reached the Western India States in July and egglaying was reported in July and August from Palanpur and Santalpur and from Idar, Hadol and Valasna in the Mahikantha Agency. Damage to young crops by locusts (presumably hoppers) in the Kadi division (Mehsana area) of Baroda State in August is on record.

There would appear to have been, on the whole, very extensive breeding in most parts of Rajputana and the Punjab, as well as in the Thar area of Sind and the northern parts of the Western India States Agency during the summer of 1897, from which the large swarms which spread east as far as Bengal and south as far Thana in Bombay in the autumn months were derived.

IV. *Autumn* 1897. (September to November 1897).

Summer breeding.—Breeding continued in most places till the end of September but in some areas hoppers were still to be found till the middle of October. Adults of the new generation began to appear by the beginning of September, and flights of pink locusts were reported from Sind and Punjab by the middle of September.

Autumn flights: Baluchistan.—Large flights appeared in Lasbela State in September and October and caused considerable damage to crops. Swarms also appeared in Barkhan causing destruction of kharif crops. On the 29th November, a swarm is said to have passed through Musakhel (Zhob district) damaging young wheat. All these are evidently instances of west-bound migration of swarms from Sind and the Punjab, passing towards Iran.

Sind.—Autumn flights appeared all over the Province by the middle of September and in some cases the swarms were large enough to appear like clouds obscuring the sun, as at Kambar in Shikarpur district. The flights continued till December and extensive damage to crops was reported in some areas in Upper Sind Frontier, and in some cases, crops were said to have been prematurely harvested for fear of locust damage.

Punjab.—Flights were in progress in September, October and November. In the south eastern districts the direction of flights was generally towards east or south-east, but in the rest of the province, the general trend was towards the west or north-west, especially in November and December. In the sub-montane areas swarms were found entering the hill valleys as in Simla, Hazara, and Rawalpindi. In November-December, some flights penetrated into the Jammu area of Kashmir State.

Rajputana.—In Jaisalmer, numerous flights were reported in autumn and the majority showed a westerly or south-westerly trend. In east Rajputana, numerous flights were reported in September, October and part of November, which would appear in most cases to have passed eastwards into Central India and the United Provinces.

United Provinces.—Swarms were found in various districts during September, October and November, but in November reports were confined to Pilibhit, Dehra Dun and Almora.

Cenral India.—During October, swarms would appear to have passed through the various parts of Central India: through Gwalior, Bundelkhand, Bhopal and Malwa, into the Central Provinces. Early in October

a large swarm is said to have flown over Jhabua southwards into Jobat and a second towards the end of October east to west over Jhabua, possibly, into the Mahikantha tract.

Central Provinces. Locusts were first observed in the first week of October in Saugor and Hoshangabad areas, presumably from parts of Central India and during subsequent weeks spread into Damoh, Jubbulpore, Narsinghpur, Mandla and Seoni to the east and into Nimar and Chhindwara (and probably also Berar) to the south. The swarms, that were reported on the 27th October at Kopergaon in Ahmednagar and at Sinnar in Nasik in Bombay Presidency, had their origin probably from Nimar and Berar *via* Aurangabad district (Hyderabad). The swarms in the Jubbulpore and Mandla areas presumably passed further east into Bihar and Bengal during November and December.

Bombay Presidency.

(1) *Western India States and Gujarat.* Locusts were reported from Jamnagar and Gondal in Kathiawar early in October, and further reports were received during October and November from Rajkot, Morvi and Jamnagar. On the 19th October, a swarm of locusts was noted in Broach coming from east from Rajpipla Hills and at the same time another flight was noticed in Sadra near Prantij also coming from east. On the 28th October, flights were recorded in Kaira district (Kapadvanj and Borsad) coming from north-east and another on the 1st November in the Nadiad taluka, also from north-east. On the 27th October, a visitation of great swarms of locusts coming from the east was reported at Sinnar in Nasik district and on the same date, flights were observed at Kopergaon in Ahmednagar coming from the south-east and departing towards Sinnar. These swarms apparently ultimately reached the northern part of Thana in 1897, according to information given in the Annual Report of Department of Land Records and Agriculture in Bombay for 1897-98. As already stated, these were probably derived from the swarms visiting Nimar and Berar.

Apparently at this time north-easterly winds were prevalent all over this area and had brought the locusts into Gujarat, Panchmahals and north Bombay from Central India and Central Provinces.

In November, locusts would appear to have spread from Broach further south into Surat and Nandurbar (west Khandesh).

Bihar and Bengal. Swarms from Central India and Central Provinces reached Shahabad district in Bihar on the 15th and 16th November (the direction of flight being south to north), and Palamau district from the 12th November onward. During November and December, locusts also visited the Aurangabad area of Gaya district. and parts of Muzaffarpur, Singhbhum, Bhagalpur and Sonthal Parganas districts. In Bengal, the earliest report is from Burdwan Division in October-November. In the course of November and December, some swarms reached Jalpaiguri and Pabna in the north, but most of the flights would seem to have been directed into the southern parts of the province: 24-Parganas, Jessore, Khulna and Nadia; Dacca, Faridpore and Backergunge; and Tipperah and Noakhali districts and in many places considerable damage to crops was caused. The easternmost limit of autumn flights in 1897 was (91°E. Long). in Noakhali and Tipperah districts.

Summary of Events in 1897.

(1) The winter and spring rains were, on the whole, rather poor in southern Iran and East Arabia, except for November 1896 when Muscat recorded 3.04″ rainfall. If this record should be typical for east Arabia,

winter breeding should be considered to have been possible. On the other hand, rainfall in Upper Persia and Upper Baluchistan, and in north Punjab was distinctly heavier.

(2) Overwintering swarms were present in small numbers in Sind till March and also a few in Punjab and Kumaon in January but none later on.

(3) Presumably on account of poor spring rains in the southern Iran, spring flights appeared early in Upper Baluchistan, and in view of favourable rainfall, eggs were laid by the end of March and the beginning of April in the Quetta-Pishin and Zhob areas, in Chagai district and in the Kandahar area of Afghanistan.

These flights reached the Punjab in April and oviposition occurred in the North West Frontier and northern Punjab.

(4) Summer flights commenced early by middle of May and reached as far east as Purnea in Bihar by end of June.

(5) The monsoon rainfall was fairly heavy and wide-spread in north-west India, in the desert as well as on the plains, and led to heavy breeding in Rajputana—east and west, in the Thar area of Sind, in sixteen districts of the Punjab, and in Western India States (Palanpur and Idar).

(6) Autumn flights commenced in September and the eastern flights covered Central India, United Provinces, Central Provinces, Bihar, and Bengal (as far east as Tipperah) by December; and towards the south spread into Kathiawar and north Gujarat and reached as far as Nasik, Thana and Ahmednagar in Bombay. There were also extensive flights in Sind, Baluchistan and Punjab.

YEAR 1898

A.—WEATHER DATA 1898

I.—*Winter-Spring Rainfall* 1897-1898 (*in inches*)

1897-1898	November	December	January	February	March	April
Iran :						
Bushire	..	0·92	1·33	..	4·69	..
Jask	..	0·11	..	..	2·33	..
East Arabia :						
Muscat	..	..	0·08	0·11	1·43	..
Baluchistan :						
Quetta		1·24	0·12	1·39	3·56	..
Chaman		1·03	0·32	0·46	1·67	..
Kalat		1·02	0·02	0·78	2·27	..
Sind :						
Karachi:	..	..	..	..	0·43	..
N.W.F. Province :						
Peshawar	..	1·25	0·05	2·60	2·35	0·42
Bannu	..	0·85	0·04	2·40	1·17	0·11
Punjab :						
Rawalpindi	..	1·25	1·35	2·9	0·68	0·02
Gujarat	..	0·08	0·32	4·93	..	..
Jullundur	..	..	0·54	9·65	..	..
Hissar	..	..	0·03	1·48	..	..

Winter rainfall was poor in south Persia and Oman, but was slightly better in Upper Baluchistan, N.W. Frontier and Punjab. In spring, fairly good rain fell in March in most of these areas, except the Punjab, where heavy rainfall occurred, on the other hand, in February.

II.—*Monsoon Rainfall* 1898 (*in inches*)

1898	May	June	July	August	September
Sind :					
Karachi	..	..	2·17	0·17	0·57
Mithi	1·27	..	2·06	..	0·40
Chachro	0·51	.	1·22	..	0·43
Umarkot	0·31	0·18	4·61	..	1·15
Rajputana :					
Barmer	..	2·14	8·49	..	0·74
Jodhpur	0·64	..	6·36	..	2·40
Jaisalmer	0·11	1·65	0·79	..	0·30
Bikaner	1·62	0·79	2·37	0·50	1·54
Jaipur	1·31	2·62	11·43	0·87	3·02
Ajmer	0·40	0·70	6·80	1·57	2·86
Punjab :					
Rawalpindi	1·13	0·44	10·48	4·16	10·78
Gujarat	1·35	0·10	8·84	4·40	2·98
Jullundur	0·07	3·48	7·87	3·12	2·33
D.G. Khan	0·53	0·12	2·41	..	3·67
Hissar	2·02	2·15	3·87	0·24	0·69
N.W.F. Province :					
Peshawar	1·37	0·05	4·22	0·40	1·4
Bannu	0·79	0·07	6·73	..	0·3

The monsoon was erratic in 1898. It apparently began early, but there was little rainfall in May and June. In July there was heavy rainfall in most places though there was little in the Thar area, in north Jaisalmer and in Bikaner. August proved to be a dry month in most places except in the Punjab. In September there was general, though light, rainfall in most places.

B.—Locust Data 1898.

I. *Winter* 1897-98. (December 1897 to February 1898).

There were overwintering swarms in many parts of northern India. There is no direct information for Baluchistan, but in Sind, numerous swarms were reported throughout the province till the 8th March. Presumably most of the Sind swarms migrated westwards into Baluchistan as usual.

In Rajputana, locusts were reported from Mewar in the second week of January. Several swarms were active in Jaisalmer during February and March, but none were reported in April. In January, locusts were reported from Chhattarpur State in *Central India* and also from the adjoining districts of the *United Provinces*, Jhansi, Banda and Fatehpur. A flight of locusts was reported passing south to north over Godhra in Panch Mahals (Western India States) on the 5th February.

The numerous swarms that had reached *Bihar and Bengal* in December were apparently active, moving about in January and February. In *Bihar*, flights visited Muzaffarpur (Sitamarhi and Hajipur). Saran

(Gopalganj), Patna (Fatwah and Mokameh), Gaya (Aurangabad), Hazaribagh and Palamau districts. In Bengal, flights were reported from Pabna (Sirajganj) on the 9th January and Tipperah in January and as damage to mustard crops was reported early in January from parts of Sylhet and Nowgong in Assam, it is evident that some swarms had moved from Bengal not only into the Surma valley but had flown across the Khasi and Jhaintia Hills into the Brahmaputra valley (93°E. Long).

In the *Punjab*, swarms were active mostly in the northern and central districts from Peshawar and Hazara down to Jhang and Montgomery, and as there was good rainfall in February, they were apparently settling down for breeding.

II. *Spring* 1898. (March to May 1898).

The data vailable for Baluchistan are scanty. From the administration report of the Chagai Political Assistant for 1898-1899, it is seen that 'parts of the Nushki district suffered, in addition to the want of rain, from an invasion of locusts, which came from the direction of Kharan. Kharan also suffered severely from a similar visitation'. According to the Baluchistan District Gazetteer, Vol. VI. Sarawan, (1907), 'great damage was caused by locusts to crops in 1898 in Sarawan'. It is likely that the locust invasions in question have reference to the spring migrations of swarms of the yellow locust overwintering in southern Persia and East Arabia, which had been impelled by the scarcity of winter and spring rainfall to move earlier than usual north into the uplands of Persia and Baluchistan. Possibly some of these swarms also moved across Upper Baluchistan into the Punjab.

The Punjab. Numerous swarm movements are on record in the province during March. Favoured by the rainfall in February, oviposition took place in the following districts:—Shahpur, Jhang, Gujrat, Jhelum, Rawalpindi and Gujranwala. The hoppers that emerged were destroyed as far as possible. It is stated that, in some places (Shahpur district), starlings appeared and were useful in keeping locusts under check.

Western flights. The flights from the west were first noticed in Sind during the week ending 10th May 1898 in Shikarpur district, and subsequently several other swarms were recorded in Shikarpur and Karachi districts. In the Baluchistan area, the first flight in Lasbela state occurred on the 3rd May at Kanrach, and jowar crops were damaged. In Jaisalmer, the first flights from the west arrived in Tanot from Sind on the 4th and the 5th May. Since a flight reached Kerowlee State during week ending 1st June, swarms were apparently flying rather rapidly across the Rajputana area. In the *Punjab*, they were noticed passing over the Shahpur district from the middle of May. In the Western India States, a flight from the west was recorded during week ending 24th May in Jhalia in Rajkot area.

III. *Summer* 1898. (June to August 1898).

The monsoon started early and fairly good rainfall occurred in many parts of the Punjab during June. In the desert areas, however, there were only sporadic showers during June. Rainfall was heavy and general all over North West India during July, but this was followed by a prolonged break covering the whole of August in most areas except the Punjab. Except in a few places only light rainfall occurred in September.

Summer flights. These were recorded in Sind, Punjab, and Rajputana during June, July and August. There is no information as to whether they reached the *United Provinces*, but in *Central India* they

reached Kirwai in Bhopal Agency by mid July. In east Rajputana swarms were present in July—August in Kerowli, Alwar and Bhurtpore.

Summer Breeding: In the *Punjab* oviposition occurred mostly in the eastern parts of the Province: Gurgaon, Rohtak, Delhi, Karnal, Ambala, Ludhiana and Gurdaspur, and in addition, also in Jhelum and Bannu.

In *Sind*, there was generally shortage of rainfall in the interior of the desert areas even in July, so that breeding of locust swarms should be considered improbable there; on the other hand, in *Rajputana*, fairly good rainfall occurred in July in many places, as for instance in Barmer, Sanchor, Jodhpur, Phalodi and Bap; Pandit Suraj Parkash in his note on 'Locusts in Marwar' [1900] observed oviposition in July—August, 1898, in a large area between Merta and Degana Railway Stations and also near Jodhpur. In Jaisalmer, breeding was noted in Tanot Pargana in August. It is probable that a fair amount of egg laying had occurred in the western Rajputana areas, but as there was little rainfall, in these areas in August and September, it did not extend into August and September as usual, so that breeding was confined to only one early batch and came to an end very early in the season.

IV. *Autumn* 1898. (September to November 1898).

Autumn flights. In *Sind*, several flights were reported to be active in the Upper Sind Frontier and Shikarpur districts from the 14th September to the end of the month. They were reported from Thul, Kashmor and Jacobabad and said to have come from the east or north-east and to have departed westwards. At about the same time, in *Baluchistan*, certain swarms were reported in Musakhel (Loralai district), in Fort Sandeman and Killa Saifulla tahsils of Zhob and in Sharigh tahsil of Sibi. These had presumably come from the direction of Punjab or Sind (in the case of Sharigh). After September, there is a report of locusts at Kanrach in Lasbela early in October and of damage to rice cultivation in lower Zhob in November.

In the *Punjab* flights over Lahore and Ferozepore are recorded in September, but none in October or November.

On the whole, there is a conspicuous paucity of flights in Sind, Punjab and Baluchistan during the latter part of autumn, and it would appear that, as there was little breeding in August and September, the adults of the July batch of breeding had left the desert in a body westwards in September.

In eastern Rajputana, locusts were present in Alwar in August, after which there are no reports of flights. In October and November, howver, reports of damage to autumn crops by 'young locusts' (possibly hoppers) in *Kherwara* situated south-west of Mewar (on Mahikantha border) occur in the season reports of the Gazette of India. It is probably a case of late breeding due to favourable rainfall in September.

Autumn flights are recorded in Bihar in Manbhoom district in October and Saran district (Gopalganj) in November. Some flights would appear to have reached Cuttack in *Orissa* during week ending 26th October 1898.

Swarms were reported from the sea coast villages of Olpad taluk in Surat district, *Bombay* damaging *bajri*, during the first week of September, and about this time locusts are said to have visited the Alirajpur State of Central India, situated on the borders of Rewa Kantha of north Gujerat.

Summary of Events in 1898.

(1) Winter rainfall was poor in southern Iran and Oman, and was slightly better in Upper Iran and Upper Baluchistan. There was good rainfall in February in the Punjab and in March in Upper Baluchistan.

(2) There were fair numbers of overwintering swarms in Sind, and north Punjab, and also in parts of Bihar, United Provinces, Bengal, and Assam (Sylhet and Nowgong). Presumably there were good numbers of overwintered locusts in southern Baluchistan and Iran.

(3) Yellow locust swarms would appear to have left the coastal regions of southern Iran early on account of the prevailing drought and to have flown across Kharan into Chagai and Sarawan, and possibly into the Punjab. Spring breeding, however, occurred only in north Punjab.

(4) Western summer migration commenced by the middle of May and reached as far as Central India.

(5) Monsoon rainfall was erratic and poor except for heavy rains in July. August was completely dry. Summer breeding was limited to July and August and occurred in parts of west Rajputana and east Punjab.

(6) Few autumn flights were observable after September. Westward flights were reported in Sind and Baluchistan, and eastward flights reached Bihar and Orissa in October. A few flights reached as far as Surat in the south.

YEAR 1899

A.—Weather Notes 1899

I.—*Winter-Spring Rainfall* 1898-1899 (*in inches*).

1898-1899	November	December	January	February	March	April
Iran:						
Bushire	2 65	1.90	0.90	2.01	0 02	..
Jask	0.16	0.02	0.10	0.38	0.73	..
Meshad	0.90	0.24	0.05	1.36	2·38	0.69
East Arabia:						
Muscat	0·55	0.10	..	0.29	1.56	..
Baluchistan:						
Quetta	0.03	0.41	0·02	2.01	2.11	0.10
Chaman	..	0.16	0.02	2.78	0.86	0.02
Kalat	..	0.44	..	1·74	0.47	0·03
Sind:						
Karachi	..	..	..	..	0.36	..
N.W.F. Province:						
Peshawar	..	0.40	..	3.07	2.65	1.24
Bannu	..	0.07	..	1.42	3.03	0·24
Pun ab:						
Rawalpindi	..	0·88	..	2.08	0.68	1.11
Gujrat	..	0·56	..	0.97	0.55	0·08
Hissar	..	1·01	..	..	..	..

Winter rains were poor; spring rains also poor in south Iran but fairly good in Oman. In Baluchistan and north Punjab, spring rainfall was fairly good.

II.—*Monsoon Rainfall* 1899 (*in inches*).

1899	May	June	July	August	September
Sind:					
Karachi	..	..	..	0·09	..
Mithi;	0.10	..	..	..	..
Chachro	..	0·09	..	..	..
Umarkot	0·06	..	..	..	..
Rajputana:					
Barmer	0·05	0·34	..	..	..
Jodhpur	..	0·43	..	..	0 52
Jaisalmer	..	..	..	..	..
Bikaner	..	0·57	0 46	..	0·11
Jaipur	0·36	5·10	5·64	..	0·22
Ajmer	0·20	3·38	4·91	0·10	0·45
Punjab:					
Rawalpindi	0·11	2·55	7·17	4·72	2·47
Jullundur	..	2·65	2.63	1·78	..
Hissar	..	1·62	0.50	..	0·09
D.G. Khan	..	0·05	..	0·14	..
N.W.F. Province:					
Peshawar	0·20	0·17	0·85	0·95	..
Bannu	0·10	0·78	3.07	0·41	..

The monsoon of 1899 was a thorough failure in Sind, Western Rajputana, North Gujarat and Baluchistan, though fairly good rainfall was received in north, central and east Punjab. In Marwar, some rain fell in areas adjoining the Aravalli Range, such as Bali, Desuri etc.

B.—Locust Data 1899.

I. *Winter* 1898—1899. (December 1898 to February 1899).

There are no data for the winter period in Sind, Punjab, Baluchistan or Rajputana. In Bihar, however, locust swarms would appear to have been seen in Hazaribagh district in January to February.

Persia. According to Predtechensky [1935] 'there are some records to show that there was a locust invasion in Persia in 1899. Specimens of locusts collected at Isfahan in 1899 by Semaka are in the possession of Uvarov'.

II. *Spring* 1899. (March to May 1899).

Neither swarms nor gregarious breeding were noticed in any part of Baluchistan or Punjab. It is possible, however, that some spring breeding had occurred in Oman or East Arabia.

Western flights: *Sind*. Swarms from the west began to appear in Sind during the second week of May. Flights from Kachhi passed over Shahdadkot on the 9th May towards Kashmor and thence to Thul on the 11th May. Locusts appeared at Johi and Manjhand and in Kohistan in Karachi district; and at Hala in Hyderabad.

Rajputana. Swarms from Bahawalpur passed over Kishengarh and Shahgarh into Khairpore territory between the 25th and the 27th May. Large yellow swarms are said to have come into Sirohi from Jalore on the 1st June and after flying about in the State to have passed out into Marwar (Bali).

III. *Summer* 1899. (June to August 1899).

Continuation of summer flights. The flights noticed in May apparently passed very rapidly eastwards in June for, during the first and second weeks of June, locusts are said to have appeared in Dacca sub-division in Bengal and to have damaged paddy plants. In Bihar, locusts appeared during the second week of June in Sonthal Parganas and in the third week passed through a portion of Patna district. About this time swarms were also observed in Monghyr and in the Siwan division of Saran district.

In *Central Provinces,* locusts appeared in parts of Saugor district during the second week of June and in the *United Provinces* locust flights are reported to have passed over the Allahabad, Hamirpur and Partabgarh districts during the same week. Further flights occurred in June and July in some parts of the Province.

In *Baluchistan,* the appearance of locusts was reported during the second week of June in several parts of the Lasbela State and in the Levy Tracts district and all the grass in these areas was said to have been eaten up causing a scarcity of fodder.

In the *Punjab,* locusts visited the 'Thal' tract of Bhakkar Tahsil in Dera Ismail Khan district during the last week of July after which there were no further reports. In *Rajputana,* damage to maize etc., by locusts was reported in Kerowli and Kherwara in July.

As 1899 was an unusual year, with an extremely poor monsoon in most parts of North West India excepting northern and submontane Punjab, there was apparently no breeding except perhaps in parts of Marwar bordering the Aravali Range. Owing to the general drought and the consequent lack of vegetation, the western flights would appear to have very rapidly advanced in May-June from the borders of Sind eastwards as far as Bengal in the course of 3 weeks.

IV. *Autumn* 1899. (September to November 1899).

Autumn flights. There were no reports of flights in autumn in Sind, Punjab or Rajputana, *except for one record* as to the appearance of locusts in the Hala taluk of Hyderabad district during the last week of October.

Western India States.—In December 1899, it was reported that swarms of locusts coming from the direction of Thar-Parkar through five villages in the Radhanpur State, damaging a few fields of one village and proceeded westwards (*Annual Report of Department of Agriculture and Land Records: Bombay for* 1899-1900).

Summary of events in 1899

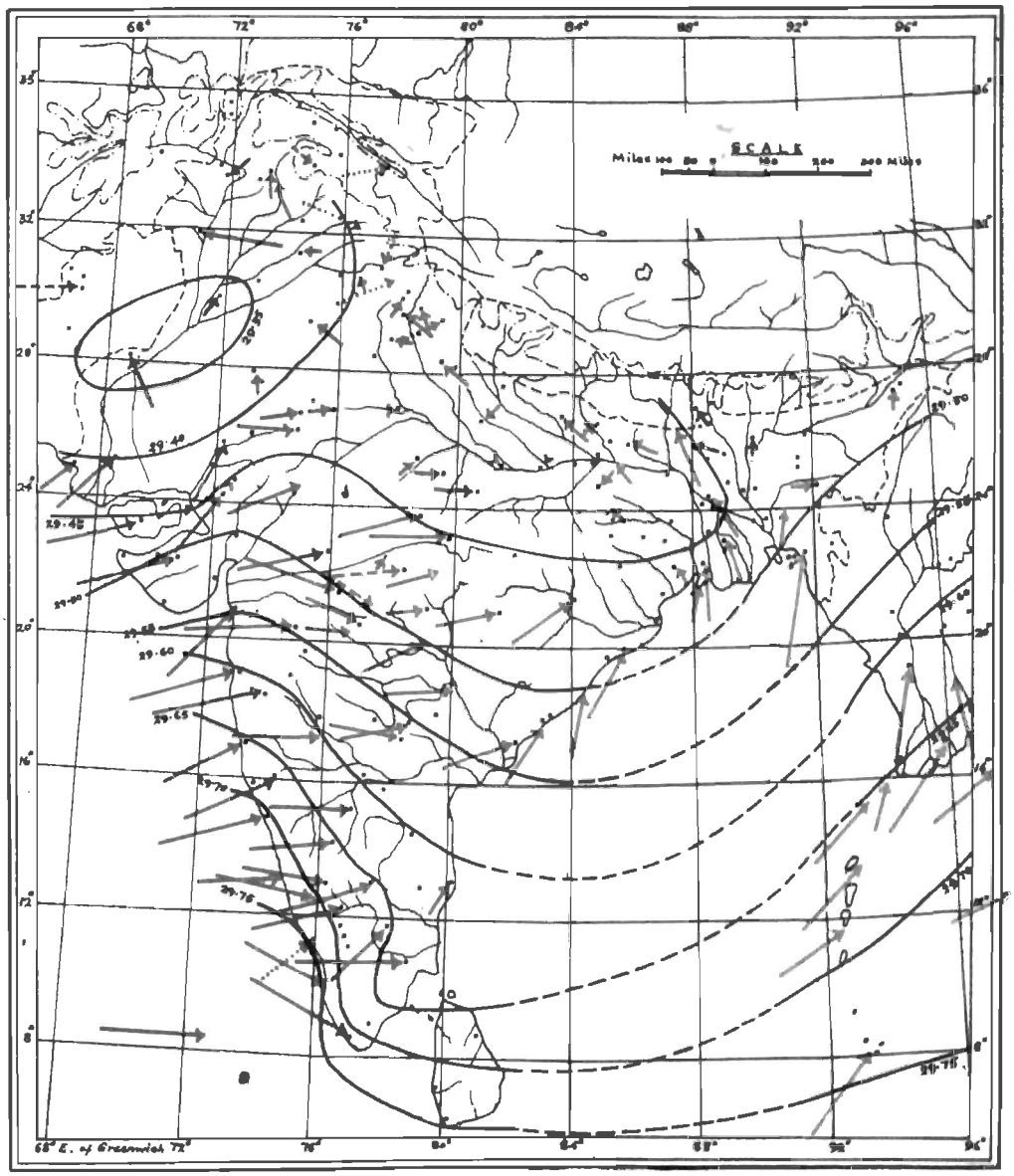
(1) Winter and spring rainfall in south Persia and Oman was poor except during the month of March at Muscat.

(2) There were no overwintering swarms in N.W. India.

(3) Summer flights began to enter Sind, Rajputana and Baluchistan by the middle of May. Owing to the drought during summer, the swarms would appear to have rapidly advanced across Rajputana, the United Provinces and Central Provinces into Bihar and Bengal; in fact, locusts were reported damaging paddy as far east as the Dacca district early in June.

(4) Owing to monsoon failure, there was no breeding anywhere, except possibly in parts of Marwar adjoining the Aravali Range.

(5) Autumn flights were absent except for two solitary cases: (1) in Hala district in Sind in October and (2) in Radhanpur State in December.



NORMAL DISTRIBUTION OF PRESSURE AND WIND IN INDIA AT 4 P.M. IN JULY
(AFTER CLIMATOLOGICAL ATLAS OF INDIA)

CHAPTER III

LOCUST CYCLE—1900 to 1907

YEAR 1900

A. WEATHER NOTES 1900

I.—*Winter-Spring Rainfall* 1899-1900 (*in inches*)

1899-1900	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Iran							
Bushire	1·74	3·98	1·82	6·65	0·02	..	..
Jask	0·80	2·77	1·54	1·70	..	..	..
Meshed	1·18	2·02	..	0·88	1·00	2·19	1·6
East Arabia.							
Muscat	..	0·02	2·53	1·32	0·65	..	..
Baluchistan.							
Quetta	0·54	0·62	2·04	2·59	0·01	1·63	1·79
Chaman	0·16	0·66	1·23	2·59	0·58	1·45	..
Kalat	0·37	0·59	0·72	1·13	0·46	0·72	0·10
Sind.							
Karachi	0·10	..	..	..	..	..	..
N.W.F. *Province*							
Peshawar	..	0·05	1·57	1·37	0·90	1·99	0·20
Bannu	0·10	0·10	1·06	0·71	1·41	2·67	0·10
Punjab.							
Rawalpindi	0·03	..	3·49	1·31	0·91	3·75	0.11
Jullundur	..	..	1·59	0·22	0·10	1·32	..
Hissar	..	..	0·30	0·08	0·25	0·62	0·51

Winter-spring rainfall was fairly good in south Persia and in Oman. Spring rainfall was middling in Baluchistan and rather poor in Punjab and N.W. Frontier.

II.—*Monsoon Rainfall* 1900 (*in inches*,

1900	May	June	July	Aug.	Sep.
Sind.					
Karachi	..	..	0·10	1·57	0·02
Mithi	..	..	0·77	7·61	0·72
Chachro	..	..	2·31	8·35	2·44
Nagar Parkar	..	..	1·20	13·34	1·41
Rajputana.					
Barmer	0·52	..	0·10	3·52	2·15
Jodhpur	0·62	1·33	1·50	5·54	6·49
Jaisalmer	..	..	0·57	2·05	1·70
Bikaner	0·17	0·20	1·02	3·94	8·24
Jaipur	2·91	0·73	0·14	5·79	5·54
Ajmer	0·11	..	3·98	2·12	7·37
Punjab.					
Rawalpindi	2·25	..	6·93	4·93	6·45
Jullundur	0·07	0·19	8·60	18·18	8·23
Hisar	0·41	0·39	2·14	6·34	7·32
N.W.F. Province.					
Peshawar	2·36	0·07	0·19	1·34	0·71
Bannu	2·12	0·43	1·25	0·47	3·28

Monsoon began late. In July there was only light rainfall except in Punjab, Jaipur and Ajmer. In August good to heavy rainfall occurred in most places except in N.W.F. Province and in September rainfall was generally heavy except in parts of the desert and N.W.F. Province.

B. Locust Data 1900

I. *Winter* 1899-1900: (Dec. 1899 to Feb. 1900)

Swarms were reported to have passed through Radhanpore State in December 1899.

II. *Spring* 1900: (March-May 1900): No data.

III. *Summer* 1900: (June—August 1900)

Western Flights: *N.W. Frontier Province*: *June.* Locusts visited Pezu, Chuhar Khel and Hiat Khel of Bannu District in June and disappeared by July. In the second week of July, locusts appeared in the northern part of Dera Ismail Khan.

Baluchistan: In his report on the Administration of Chagai district for 1900-01, Webb Ware mentions that "a visitation of locusts was responsible for an almost entire destruction of autumn crops in Chagai district." According to the Baluchistan District Gazetteer VI—Sarawan: "In 1900 there was a severe locust visitation which devastated the greater part of the cultivation." These data would indicate that an incursion of locusts of considerable magnitude from Persia or Afghanistan, had occurred in June-July, in the western parts of Baluchistan attacking the standing crops—spring and summer crops in Sarawan and, possibly, young autumn crops in Chagai.

Rajputana. The earliest report of swarms in Rajputana is from Bap on the 25th August when locusts arrived from Phalodi in Marwar. On that date it is also mentioned that "young ones"—black and yellow in colour were present though in small numbers. This would indicate that the parent locusts responsible for the appearance of the hoppers had visited this area at least a month earlier (*i.e.* in July) and had laid eggs. This is quite likely as some rain had fallen in this area in July. After the heavier precipitation recorded in August and September in Rajputana, fairly widespread egg-laying is likely to have occurred.

Sind. No records for Sind up to the week ending 18th September when swarms appeared in Chachro and Mithi talukas.

IV. *Autumn* 1900: (September—November 1900)

Autumn Breeding: *Sind.* The first report of occurrence of flights was in the third week of September, when apparently swarms from the Rajputana areas reached the Thar area, presumably under the influence of some of the Bay depressions. By the end of September, some of the swarms were reported to be laying eggs in the Mithi and Nagar Parkar talukas. It is probable that breeding had extended to Diplo and Chachro talukas also.

Rajputana. There is information only for Jaisalmer, and it would appear that hoppers were noticed in September in five of the Parganas: Bap, Jaisalmer, Dewa, Tanot and Nachna. Since good rainfall had occurred in Bikaner and Marwar also in August and September, breeding had doubtless occurred in these areas also. Indeed it is certain that hoppers had come into existence in Mallani, since it is on record that experiments with a locusticidal fungus were conducted there.

It is thus seen that both in Thar and in Rajputana, there was late breeding leading to a late production of swarms, a good many of which apparently passed the winter within Indian limits.

Autumn Flights: *Sind*. Numerous flights were reported all over Sind, many of which caused considerable damage to standing crops. Ultimately most of these swarms gradually passed out of Sind into Baluchistan.

Rajputana. Numerous swarms were active in autumn in Jaisalmer, Bikaner, Marwar and Shahpura and probably in many other parts, and much injury to crops was reported.

Baluchistan. In November, locusts were reported in the Gandhawa area of *Kachhi* and in the Saroona ilaqua of *Jhalawan* where good crops of *jowar* were destroyed by them. In December, swarms appeared in *Marri-Bughti* country and in *Sibi* tahsil and in many parts of the *Lasbela* State and in the Levy Tracts.

Punjab. Autumn flights were reported from Multan in November and from Dera Ismail Khan, Multan and Jhang in December.

North Gujarat. Some swarms were reported from Broach in November and from Ahmedabad in December.

Summary of Events in 1900

(1) There were no overwintering swarms in India.

(2) Winter-spring rainfall was fairly good and favourable for spring breeding in southern Persia and in Oman.

(3) Western migration probably occurred in summer in Chagai and Sarawan; as also in Sind, Rajputana and Punjab, but there are no definite data for June-July except in the North West Frontier (in Bannu and Dera Ismail Khan districts).

In August swarms were known to have been present in Jaisalmer and hoppers also were found in Bap, so that breeding was already in progress by that time there.

(4) Swarms reached Thar-Parkar district about the middle of September from Rajputana and breeding occurred in September-October. In Jaisalmer—and presumably also in Marwar and Bikaner—breeding occurred at this period, as there were good rains in August and September all over North West India.

(5) Autumn flights were reported in Sind, Punjab, Baluchistan and Rajputana, and a few flights would appear to have reached north Gujarat.

YEAR 1901

A. Weather Data 1901

I.—*Winter-Spring Rainfall* 1900-1901 (*in inches*)

1900-1901	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Iran.								
Bushire	1·05	1·92	3·82	1·22	..	0·09	0·27	..
Jask	0·17	0·82	2·90	0·60	..	..	..	..
Meshed	0·09	0·92	0·70	0·01	..	0·31	0·90	1·89
Ispahan	0·71	0·35	0·05	..	..	1·36	0·47	0·82

Spring Breeding. No detailed data are available for *Chagai* and it is not possible to say if oviposition had occurred, though it is very likely. In Quetta-Pishin area, hoppers were found in numbers at Kasi, Brewery and Nau Hissar in Quetta valley, at Kuchlak, Bostan, and throughout the Pishin valley in Pishin tahsil and at Sanzal and other places in the Chaman area. In the *Zhob* district breeding occurred in Kibzai, Kingri and Hindubagh areas, and in *Thal-Chotiali,* in Shahrigh, Kach-Kowas and Ahmadun areas. In *Sarawan,* great numbers of hoppers were said to have been encountered in the latter half of May on the road at Mastung, Mungachar and Kalat.

In *Afghanistan,* the Registan was said to have been full of eggs and at Buldak, 800 men had been employed to save the Amir's garden from hoppers. As in 1897, the valleys of the Kadanai, the Maruf, the Salessun, the Arghastan and the Tarnak were infested and much of the cultivation and many of the gardens were destroyed. According to Webb-Ware's reports, Garmsel and Shorawak were also similarly infested.

In *Persia,* Webb Ware reported early in May that Kirman, Narmanshir, Mashkhel, Sarhad and Seistan had been infested by locusts. According to Predtechensky [1935], Zarudni passing through *Eastern Persia* north to south first met with large swarms of the yellow locust (21st Feb.) in the eastern part of *Persian Baluchistan* between Dizak and Dehak (about 28° N.Lat.). Pairing was said to have been taking place then. In the southern hills of Baluchistan and the Sarbaz region, Zarudni observed on the 12th March large quantities of hoppers considerably damaging the vegetation. In *north-eastern Baluchistan,* Zarudni found field crops being eaten up by locusts (14th May). On 31st May, he found large fields badly damaged by locusts in the villages of Rud-i-Tamindan, where swarms of pink locusts were also found moving up the river valley within two days. In Zarudni's words, "In general there were enormous masses of the locust nearly everywhere in 1901, with the exception of Seistan, which suffered little from them."

Sind. A fair number of swarms was reported in March and April in western Sind only, chiefly in Shikarpur district (Nasirabad, Kakar and Mehar talukas) and to a less extent in the Upper Sind Frontier (Shahdadkot taluka).

From the 1st week of May, swarms increased in number in these districts and also spread into Hyderabad and Thar Parkar and apparently these really represent the seasonal migration of summer swarms from the western areas.

Rajputana. The first record of a flight was that of a swarm passing over Jodhpur on the 4th May. A few swarms were also reported at the end of May in Sirohi State flying west to east.

Punjab. During March, swarms though mostly confined as in February to the western districts of Dera Ismail Khan, Dera Ghazi Khan, Muzaffargarh and Multan, were found spreading further north into Rawalpindi, Bannu and Kohat. Eggs were laid in March in Dera Ismail Khan and Multan.

During *April,* the distribution of swarms extended northwards into Hazara, Shahpur, Jhang, Jhelum, Sialkot and Gujrat and eastwards into Montgomery and Jullundur. *Breeding* occurred in Dera Ghazi Khan, Dera Ismail Khan, Rawalpindi, Peshawar, Jhelum, Hazara, Kohat and Bannu.

In *May,* the number of swarms increased and flights visited Lahore, Kangra, Sialkot, Ambala, Attock, Multan, Lyallpore, Amritsar, Rohtak, Gurgaon, Karnal, Hoshiarpur, and Gurdaspur, in fact almost all parts of the Punjab.

It is probable that a great part of these flights belonged to the summer waves of migration that had apparently started in Sind and Baluchistan from the beginning of May.

Breeding. As a result of the good falls of rain recorded in many parts of the Punjab during May, further egg-laying occurred in May-June: Rawalpindi, Peshawar, Shahpur, Sialkot, Jhelum, Dera Ismail Khan and Lahore. At Lahore, oviposition took place in sandy alluvial land on both sides of the Ravi river.

United Provinces. The western migration apparently penetrated the United Provinces in the second week of May (week ending 11th May), swarms being reported from Dehra Dun, Bijnor, Aligarh and Partabgarh (82°E Long.). Flights were observed in various other districts during the rest of May, the easternmost area reported being Basti (83°E. Long).

Central Provinces. On the 25th May, a flight of locusts passed over Damoh district; and between the 26th May and the 1st June, a locust swarm from Berar passed through parts of Wardha and Chanda and re-entered Berar; and another passed through parts of Chhindwara, Nagpur, Chanda and Bhandara districts.

Central India. On 1st June a swarm was observed at Neemuch Cantonment in the afternoon. It did not do much damage and disappeared the next morning.

III. *Summer* 1901: (June to August 1901)

Spring Breeding. Hoppers were met with in Quetta-Pishin and Zhob districts till the third week of June and in Hindubagh tahsil till 1st week of July. The hoppers began to get wings by the end of May and were flying about during the early part of June.

Summer Flights. The western migration which commenced about the beginning of May was in full progress in *Baluchistan* during June. Large swarms of pink locusts were passing over Quetta-Pishin, Sarawan, Zhob, and Thal-Chotiali during June and July, generally entering the Punjab, Sind or Rajputana areas. In June, locusts were said to have eaten up at Quetta the leaves of Poplars and the tops of Chinars, and in Sarawan (Kalat and Mastung) to have done much harm to trees, lucerne and other field crops, though wheat practically escaped damage.

According to the *Chagai* Administration Report for 1901-1902, the District experienced in 1901 the worst visitation of locusts for upwards of a generation. The frequent inroads of locusts resulted in the total loss of the kharif. Upwards of two-thirds of the date harvest in the south-western portion of the district was reported to have been destroyed by locusts.

In *Afghanistan,* many of the vine-yards of Kandahar were damaged in June, while those at Kadanai were entirely destroyed.

In *Lasbela,* numerous swarms passed through the state and over the Levy Tracts in June, causing much damage to crops and to grazing areas.

It was found that a great many of the flying locusts were infested by Sarcophagid maggots which killed the locusts ultimately.

In *Sind,* numerous flights were recorded during June, July and August. Owing to short rainfall, there was presumably no breeding in Sind.

In the *Punjab,* flights were reported from most of the districts of the province as in May. In July and August, flights reached Simla and Kangra districts and several swarms were reported from the south eastern parts of the Punjab, and at this period, several flights penetrated the Jammu area of Kashmir.

Late spring breeding continued in June in the districts of Lahore, Rawalpindi, Dera Ismail Khan, Shahpur, Peshawar. Jhelum, Sialkot and Kohat.

Summer Breeding, occurred in Delhi, Ferozepore, Gurgaon, Gujranwala and Ludhiana.

Central India. In August, the presence of locusts is recorded in parts of Dhar, Barwani, Alirajpur, Jhabua and Jobat.

Central Provinces, Hyderabad and Madras. By the end of May, some swarms reached as far south as Chanda, and south Berar (Yeotmal). During the first and second weeks of June, several swarms were reported to have been active in the Wardha and Chanda districts, as well as in Saugor, Narsingpur, Raipur, Bilaspur and Sambalpur districts to the east. It may be presumed that the flights to the south from Chanda were continued over parts of *Hyderabad State,* though there are no records of locusts in that area till the last week of June (Season Report of Gazette of India for week ending 29th June), when locust damage to young crops was reported in Makhtal, Pargi and Nalgonda talukas. In the *Madras Presidency,* however, the Collector, Cuddappa reported about a visit to Porumamilla of Badvel taluka by an army of locusts flying from west to east on 3rd June. The swarm was so large that the "sky was bedimmed for one hour as if overcast with clouds." According to the report of the Tahsildar of Kandukur, Nellore district, numerous swarms of locusts said to be "green, red, but mostly yellow in colour"—appeared at Karedu at 3 P.M. on the 4th June, flew south and were seen at Ramapatnam at 5 P.M. on the same day. Other swarms were seen at Karedu at 2-30 P.M. on the 5th June. The following information is recorded in the Report of the Operations of the Department of Agriculture in Madras for 1901-1902. "Swarms of locusts, which passed through Godavari and Kistna districts in June 1901, were identified by the Imperial Entomologist as belonging to the ordinary migratory locust—*Acridium peregrinum*". According to the Season Reports of the Gazette of India, it is seen from the report for week ending 15th June 1901, that "standing crops were damaged by locusts in parts of Ganjam district", and from the one for week ending 6th July 1901, that "locusts destroyed young shoots of crops in the Rajpura, Makhtal, Pargi and Nalgonda talukas" of Hyderabad, Deccan.

From the above data, it is obvious that swarms of the Desert Locust coming from the Berar area and from the Chanda district of Central Provinces had passed over Gulbarga and Mahbubnagar areas of Hyderabad State into Kurnool, Cuddappa and Nellore, and over Adilabad and Nalgonda districts into Kistna and Godavari. The swarms that reached Ganjam should, on the other hand, have come from the Raipur and Sambalpur areas of Central Provinces.

In this connection, a study of the Daily Weather Charts of the period in question *viz.*, 15th May to 15th June, has shown that the south-ward advance of swarms from the 26th May to the first week of June may be correlated with the development of a peculiar distribution of winds in the region of Central Provinces, Hyderabad and north Madras. At this period, there appears to have been a tendency for the formation of a tongue-like trough of low pressure hanging down from the United Provinces and extending over eastern Central Provinces up to the Orissa Coast. This trough wolud apparently be liable to change in extent from day to day and might sometimes deepen into a depression. Under its influence, northerly or north-westerly winds would develop over a region situated west of the trough, extending from Indore across Berar and Hyderabad up to north Madras. Such a development of wind circulation would be favourable for bringing swarms from northern India right down to north Madras. Wind movements more or less of this type would appear to have been prevalent from about the middle of May up to the 8th June. From the 10th June, a development of steep pressure gradients, accompanied by strong westerly or north-westerly winds of the typical monsoon type across the Peninsula, was noticeable, and from this time, the swarms present in the Central Provinces would appear to have begun moving eastwards in the direction of Bihar and Bengal, and very few flights were noticeable in the Central Provinces after the 2nd week of June.

Flights in Bihar and Bengal. During the week ending 15th June, flights were first reported in Bihar and Bengal.

In *Bihar*, swarms were observed in Santhal Parganas, Bhagalpur, Monghyr, Darbhanga, Muzaffarpur and Champaran and damage to indigo and other crops was reported. In *Bengal*, flights visited Midnapore, Bankura, Birbhum, Burdwan, Murshidabad, Hooghly, 24-Parganas, Nadia, Rajshahi, Dinajpur and Rangpur, but did not reach any districts of the Dacca and Chittagong divisions. In *Orissa*, Cuttack, Puri and Balasore were visited. In the *United Provinces*, flights of locusts are said to have passed through Barabanki, Rai Bareili, Fatehpur, Allahabad, Jaunpur and Ballia districts during the week ending 29th June, and in the week following, the districts of Budaun, Bahraich, Partabgarh, Cawnpore, Fatehpur, Allahabad, Benares, Jaunpur, Basti, Hamirpur and Banda. During the succeeding weeks, their distribution would appear to have been restricted to Almora, Garhwal, Dehra Dun, Bahraich and Budaun—mostly in the north-western portion of the province, indicating a displacement of swrams from the east to the west, from Bengal and Bihar towards Punjab, under the influence of the easterly winds of the Bay current.

A study of the Daily Weather Charts of the period in question—15th June to 31st July—shows that strong westerly winds that had developed from the 10th June had carried the locust swarms into Bihar, Bengal and Orissa by the end of June; and it is evident that the swarms did not reach Dacca and Chittagong divisions because the winds in this part of Bengal were either southerly or south-easterly.

Western Indian States and Gujarat. Information is rather scrappy for this area, but apparently the western flights reached these areas in June, though there are no definite records. During the second week of July, locusts were reported from Panch Mahals, and in the fourth week from Baroda—attacking young plants. In August, there is mention of the occurrence of locusts in Panch Mahals and Gujarat.

Rajputana. The earliest mention of locusts in Jaisalmer records is that of a yellow swarm at Nachna during the 2nd fortnight of July. A

fair number of swarms were active in July and August. There is but scanty information regarding *breeding*, but apparently a fair amount of breeding had occurred in a region enclosing the Nokh and Bap areas in Jaisalmer, the Phalodi area in Marwar and the Bikaner and Surpura areas in Bikaner, as satisfactory rainfall had been recorded in this region during July and August. Possibly breednig had taken place also in Jaipur, Ajmer and eastern Marwar areas.

IV. *Autumn* 1901: (September-November 1901).

Autumn Flights. There are very few records of swarms in the autumn months. In the Zhob district, locusts were reported on crops in September and October (Musakhel and Bori). In Lasbela State, swarms are said to have appeared in the neighbourhood of Bela in the third week of October causing damage to *jowar* and *moong*. In Kachhi, locusts visited Naushehra towards the last week of December causing damage to crops.

Sind. Numerous flights were reported in October and November from most parts of Sind and were said to be causing a fair amount of damage to crops. There are only two records for December.

Punjab. Summer Breeding. Hoppers were being found in Gurgaon, Ludhiana and Delhi till the beginning of October.

Autumn Flights were on the whole few in October, November and December, and were confined to the districts of Delhi, Jullundur, Gurgaon and Karnal in the east and to Multan and Dera Ghazi Khan in the west.

Rajputana. In September, a fairly large number of swarms were active in Jaisalmer, but there is no record for October, only one record each for November and December.

In *Sirohi* there are two reports for October. Considerable damage by *locusts or rats is* recorded in the Season Reports of the Gazette of India during October 1901 in Marwar, Sirohi, Kherwara, Kishengarh, Ajmer-Merwara, Kotah and Jhalawar. A few flights were reported in November and December in parts of Marwar, Kotah, Ajmer-Merwara, Kishengar, Mewar and Bikaner.

Central India. Flights of locusts visited the Bhopawar district of Indore on the 30th September, Rampur district on the 1st October and Khargora district on the 6th October. They came from the north and passed on to the south. In Rampur district: *juar, makki, til* and cotton were affected. In October-November, locusts were reported also from Bhopal, Bhopawar, Indore and Gwalior.

United Provinces. Locusts were reported from Shahjahanpur in September, from parts of Dehra Dun in October and from Cawnpore, Garhwal, Budaun and Hardoi in November. In December they were recorded from Almorah and Nainital in the third week.

Western Indian States. Damage to crops by locusts in the third week of September in Rajkot is recorded in the Bombay Season and Crop Reports. In October, damage by locusts was reported from Ahmedabad and Kaira districts and from Rajkot and Baroda (Kadi division), and from Panch Mahals. In November, there were reports from Rajkot and Baroda (Kadi). In December swarms are said to have appeared in Jamnagar, parts of Porbandar and Bhika Taluka and damaged wheat and cotton slightly.

On the whole, owing to the restricted summer breeding, autumn flights were few both in the west in Sind and Punjab, and in the east, they reached only up to Gwalior. In the south, they spread only up to Kathiawar.

Summary of Events in 1901 (*Vide* Pl. 58).

(1) There was fairly heavy rainfall in December, in Iran, Oman and Upper Baluchistan, but otherwise both winter and spring rains were defective. Spring rainfall was fairly good in Baluchistan and north Punjab.

(2) There were overwintered swarms in Sind and Kachhi and west Punjab which gradually migrated into Musakhel, Sharigh, Loralai and Bolan in February-March, and laid eggs in Quetta-Pishin, Zhob, and Sibi. Other swarms from south Iran also migrated into Kharan, Chagai and Afghanistan areas and laid eggs in extensive areas. Breeding also occurred in various parts of Upper Persia.

(3) There were numerous flights in spring in the Punjab, mostly in the north, where egglaying occurred in March-April. Further egglaying occurred after the fairly heavy falls of May, in north and Central Punjab in May-June.

(4) Migration from the west commenced in May and reached Sind Punjab, Rajputana, the Central Provinces and United Provinces during the month.

(5) Early in June, flights passed, under the influence of northerly winds, from Berar and Chanda and Nagpur districts of Central Provinces into Hyderabad areas and thence into Cuddapa, Nellore, Kistna and Godavari in Madras Presidency.

Towards the middle of June, the winds became westerly and numerous swarms reached Bihar and Bengal.

Some flights passed also into Western India States by middle of July.

(6) Summer breeding was, on the whole, scanty, and was confined to four of the south-western districts of the Punjab and to parts of western Rajputana.

(7) Autumn flights occurred in Sind, Baluchistan and Rajputana, and in parts of United Provinces and Central India, and in parts of Western India States. Owing to restricted breeding, autumn flights were comparatively few.

YEAR 1902

A. Weather Notes, 1902

1.—Winter Spring Rainfall in 1901-1902 (*in inches*)

1901-1902	Nov.	Dec.	Jan.	Feb.	Mar.	April.
Iran.						
Bushire . .	..	1·49	1·04	0·04	0·26	0·39
Jask . .	..	..	0·05	0·62	..	..
Meshed . .	1·07	0 28	1·89	1.30	1·35	1·41
Ispahan . .	0·31	0·53	0·67	0.14	1·42	0·90

1901-1902	Nov.	Dec.	Jan.	Feb.	Mar.	April
Arabia.						
Muscat	..	0·52	..	0·28	..	0·27
Bahrein	..	0·58	..	0·01	0·04	0·26
Sind.						
Karachi	..	0·01	..	..	..	..
Baluchistan.						
Quetta	..	..	0·07	0·04	0·54	0·50
Chaman	..	..	0·25	0·01	0·17	0·04
Nushki	..	..	0·19	0·03	..	0·23
Kalat	..	..	0·02	..	0·14	0·29
N. W. F. Provinces.						
Peshawar	..	..	..	0·10	0·72	0·50
Punjab.						
Rawalpindi	..	..	..	0·01	1·00	1·77
Gugrat	..	..	..	0·25	1·09	1·03
Hissar	..	0·06	..	0·28	0·03	0·48

Both winter and spring rains were a failure in south Perisa and Oman and North West India. In the Punjab there was light rainfall in March-April.

II.—*Monsoon Rainfall* 1902 (*in inches*)

1902	May	June	July	Aug.	Sept.
Baluchistan.					
Quetta	0·10	0·48	0·07	..	..
Kalat	0·15	1·21	..	0·10	..
Sind.					
Karachi	2·26	12·22	0·01	2·87	4·42
Jacobabad	0·06	0·27	..	1·18	0·50
Mithi	..	0·67	2·41	7·82	4·21
Chachro	..	0·14	0·97	8·27	1·37
Rajputana.					
Barmer	0·10	1·73	..	1·91	2·30
Jodhpur	..	2·13	0·33	3·16	1·27
Jaisalmer	0·47	2·49	0·21	0·81	1·16
Bikaner	0·07	1·84	0·93	1·42	1·41
Jaipur	0·61	1·40	4·94	3·53	8·15
Ajmer	1·45	1·75	3·48	4·70	5·44
Punjab.					
Rawalpindi	1·32	5·32	5·03	5·47	3·74
Gujarat	1·08	3·23	6·34	5·82	1·99
Jullundur	1·05	0·74	4·42	5·99	7·50
Hissar	0·74	5·14	1·79	0·71	0·98
D. G. Khan	0·10	1·37	0·11	2·28	0·74
Gujarat.					
Ahmedabad	0·35	0·07	3·55	9·69	12·30
Cutch.					
Bhuj	..	0·48	2·75	4·12	3·12

Two cyclones passed over the Karachi and Lasbela areas in May and June and caused heavy rainfall. Fairly good rainfall occurred in the Punjab and parts of Rajputana at that period. There was little rainfall in July except in parts of the Punjab. Heavy rainfall occurred in Sind, Rajputana, Punjab and Western India States in August and September.

B. LOCUST DATA 1902

I. *Winter* 1901-1902: (Dec. 1901 to Feb. 1902).

Over-wintering locusts were found all over Sind, in the Kangra, Mianwali and Dera Ghazi Khan areas in the Punjab, in the Jasrota district of Jammu (Kashmir State), in the Rajkot area (Jamnagar State), in Kathiawar, and in Dehra Dun district of United Provinces. In Baluchistan, swarms were reported to have appeared in February in the Quetta-Pishin, Thal-Chotiali and Zhob districts apparently coming up the hill valleys from the over-wintering areas in Kachhi and Dera Ghazi Khan.

II. *Spring* 1902: (March—May 1902)

The rainfall in winter and spring proved a thorough failure all over the winter-rain areas in East Arabia, Iran, Afghanistan and Baluchistan, and it is said that Chagai and the adjoining areas of Shorawak, Registan, Garmsel, Seistan, Sarhad etc., experienced the worst famine known for thirty years. In Upper Baluchistan, deficiency of rainfall was keenly felt in Quetta-Pishin, Zhob and Thal-Chotiali districts. In the Punjab too, spring rainfall was very defective. There were reports of swarm flights in March, in Quetta-Pishin, in Zhob (Musakhel and Ft. Sandeman), and Thal-Chotiali (Barkhan), but none in April and May.

There was *no oviposition and breeding* anywhere owing to defective rainfall.

III. *Summer* 1902: (June—August 1902)

There were no reports of locusts during June except in Sind, where they appeared towards the close of June in Karachi taluka. In Lasbela, locusts passed over the State during the second week of July flying towards the north-east. In the Jaisalmer records, there are no reports for June and July, but in the earliest ones on record (16-17 VIII), it is stated that young ones had hatched out at Tanot in north Jaisalmer. This would suggest that the parent swarms must have appeared much earlier (probably early in July), and had laid eggs in the wake of the heavy rainfall at the end of June. There are no records for June or July for the Punjab. Swarms were apparently present in Palanpur in July-August, and breeding had occurred in August-September in the wake of the heavy rainfall.

In the Karachi and Lasbela areas, heavy rainfall occurred in June (12·22 in. at Karachi) and breeding followed in these districts in July-August. By the last week of July, hoppers were being found in Karachi and Kohistan areas and a week or two later also in Kotri and Tatta talukas. Similar hopper infestation appeared during August in the Hab and Vindar areas of Lasbela. As rainfall was defective in the desert, there was apparently no breeding in the Thar area in July-August.

IV. *Autumn* 1902: (September—November 1902)

Late Summer breeding.—There was good rainfall in August—September in Karachi and Lasbela areas, and as a result thereof, further breeding apparently occurred in Lasbela State in the Hab area, and presumably also in the neighbouring Karachi areas.

Sind. There was heavy, widely distributed rainfall in the Thar Desert areas in August and September, which evidently resulted in wide-spread oviposition. In September and October, hoppers were found swarming all over the desert damaging grass and crops, especially in Nagar, Diplo and Mithi. The greatest damage would appear to have been done in Diplo. In general, all the crops would appear to have been destroyed.

Rajputana. Eggs would appear to have been laid in Jaisalmer Pargana by a swarm on the 2nd October and hoppers were found to have emerged by the 19th October. It is probable that similar late breeding had also occurred in other parts of Rajputana especially in the Marwar and Ajmer areas.

Punjab. According to the Season and Crop Report for the Province of Punjab for 1902-03 "Locusts appeared in the districts of Jhelum, Mooltan, Gurdaspur, Sialkot, Mianwali and Dera Ghazi Khan, but did little or no damage. Whatever eggs were deposited, every effort was made to destroy them, and apparently with success". It is not clear if breeding occurred in all the above districts or only in some of them.

Autumn Flights: Sind. There were numerous flights in almost all parts of Sind during November and December, and damage to many of the rabi crops was reported.

Baluchistan. There were several flights in Lasbela, in Nasirabad tahsil and in Kachhi during November and December. In Kachhi, barley crops appear to have been destroyed.

Rajputana. Damage by locust swarms was reported in Marwar, Jaisalmer and Ajmer-Merwara in November.

Western India States and Bombay. Swarms were reported from Broach, Baroda and Rajkot.

Central India. Damage by locusts to *jowar* was reported in week ending 22nd November in Dhar State.

Bihar. Flights of locusts were reported to have been seen in autumn in parts of Monghyr, Patna, Shahabad and Saran districts. There was some damage to standing crops.

Punjab. Swarms appeared in December in Mooltan, Dera Ghazi Khan, Hissar and Shahpur districts.

N.W.F. Province. Locusts appeared in Kulachi tahsil of Dera Ismail Khan district in the third week of October.

Summary of Events in 1902

(1) Winter and spring rainfall proved a thorough failure in the winter rain areas of East Arabia, southern Iran and Baluchistan and Punjab.

(2) Small overwintered swarms were found in parts of Sind, Baluchistan, Punjab and West Kathiawar.

(3) There was apparently no winter or spring breeding anywhere.

(4) Owing to cyclonic disturbances, rainfall began early in May-June in south Sind and in Lasbela and parts of Punjab. July was comparatively dry, but there was good rainfall in August and September in the Sind-Rajputana area and in parts of Punjab. Summer flights from the west began at the end of June and were comparatively few. They reached up to Rajputana and Gujarat.

(5) Early summer breeding occurred in Karachi and Lasbela areas in July-August and parts of the Rajputana desert and late summer breeding occurred in the whole of the Thar Desert and probably in parts of Marwar, Jaisalmer and Ajmer-Merwara.

(6) Autumn flights were noticed in Sind, Baluchistan and Punjab and also to a slight extent in Central India, Kathiawar and Gujarat: flights reached Bihar by end of autumn.

YEAR 1903

A. Weather Notes 1903

I.—*Winter-Spring Rainfall* 1902-1903 (*in inches*)

1902-1903	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Iran.							
Bushire	0·38	6·07	3·03	0·29	0·21	0·48	0·71
Jask	0·28	..	0·67	1·51	..	..	0·23
Meshed	1·52	1·55	1·26	1·73	1·04	4·40	1·36
Ispahan	..	4·05	1·47	0·47	0·07	0·99	0·23
East Arabia.							
Muscat	1·00	..	0·52	0·40	..	..	0·23
Bahrein	0·15	0·10	..	0·09	1·42	0·31	0·35
Baluchistan.							
Quetta	0·98	0·59	0·47	1·02	1·19	5·30	2·71
Chaman	0·85	0·15	0·96	0·35	..	3·94	1·94
Nushki	..	..	0·28	0·94	0·44	4·11	1·37
Sind.							
Karachi	..	..	..	0·45	..	0·98	..
N. W. F. Province.							
Peshawar	0·53	0·03	..	1·52	..	3·53	1·27
D. I. Khan	?	..	..	0·12	0·08	1·47	0·96
Punjab.							
Rawalpindi	1·10	0·07	..	0·75	0·10	3·92	0·30
Gujrat	0·15	..	..	0·56	0·18	3·00	0·14
Mianwali	?	..	..	0·14	..	0·98	0·47
Jullundur	0·15	..	..	2·16	..	2·19	..
Hissar	..	..	..	0·77	..	..	..
D.G. Khan	0·16	..	0·05	0·00	..	0·55	0·15

Winter rainfall began early in October, but was defective in Arabia, southern Persia, Baluchistan and Punjab. Rainfall in spring was fairly good in Upper Persia, Upper Baluchistan and Punjab, being fairly heavy in March in many places.

II.—*Monsoon Rainfall* 1903 (*in inches*)

1903	May	June	July	Aug.	Sep.
Sind.					
Karachi	..	..	4·30	..	0·18
Mithi	..	..	13·98	..	0·40
Chachro	0·01	..	5·68	0·57	2·53

1903	May	June	July	Aug.	Sep.
Rajputana.					
Barmer	0·40	..	5·23	0·08	0·98
Jodhpur	0·88	..	8·82	5·58	4·43
Jaisalmer	0·03	..	2·30	1·19	0·30
Bikaner	0·03	0·40	4·84	2·44	2·30
Jaipur	0·49	0·20	6·62	11·79	4·71
Ajmer	0·26	0·19	8·70	7·38	1·29
Punjab.					
Rawalpindi	2·80	0·62	3·79	7·98	3·16
Mianwali	0·77	0·20	3·87	1·41	1·10
Ferozepore	0·77	0·06	9·39	4·48	1·69
Hissar	1·19	0·09	6·98	4·12	4·27
D. G. Khan	0·39	..	0·30	0·41	0·14
N. *W. F. Province.*					
Peshawar	2·13	0·20	0·37	0·38	0·90
D.I. Khan	0·89	0·11	2·95	9·05	4·26

There was heavy rainfall in most places in July; little precipitation in August and September in Thar, Mallani and Jaisalmer, though fairly good rainfall occurred in other parts of Rajputana and in the Punjab.

B. Locust Data 1903

I. *Winter* 1902-1903: (Dec. 1902 to Feb. 1903)

In Sind, locusts were being reported throughout the winter from the southern parts of Hyderabad district, and from no other parts of Sind. In Baluchistan, locusts were found in February in Jhalawan, Thal-Chotiali and the Bolan Pass. Flying swarms were reported to have appeared in Chaman and Pishin tahsils from the direction of Kandahar in Afghan territory. In the Punjab, swarms were reported from many of the western and central districts, and in Dera Ismail Khan in N. W. Frontier Province.

II. *Spring* 1903: (March—May 1903)

In Baluchistan, locusts were being found in March in Quetta-Pishin (Pishin and Chaman), in Thal-Chotiali (Duki) and in the Bolan Pass during the early part of March, but disappeared later. None were found in April and May. There was no breeding. According to Major C. J. Nurse, "*Schistocerca peregrina* appeared in Quetta in 1903, in large numbers in March, but a spell of cold weather killed most of them off" (Baluchistan District Gazetteer: Quetta-Pishin 1908).

In the Punjab, with the fall of rain in March, breeding would appear to have occurred in April-May in the northern districts of Punjab: Mianwali, Jhelum, Rawalpindi, Jullundur, Gujarat, Gujranwala, Sialkot, Amritsar and Lahore. By the middle of May, adults of the new generation began to fly about, and move mostly south-east into United Provinces and Central India.

In the N.W.F. Province, locusts were reported from Dera Ismail Khan in March and in the first week of May from Peshawar. Swarms were present in the Peshawar district throughout May, and presumably oviposition occurred during the month, as hoppers were reported during the first week of May in Munawar tahsil of Kashmir State, where melon, cotton and cane crops were damaged.

Summer Flights from the West. The first flights from the western spring brood areas appeared on the 24th May at Welpat in Lasbela State passing northwards, and on the 27th May at Thul in Upper Sind Frontier district in Sind. At about the same time, swarms appeared at Manjhand in Karachi district, at Sakrand in Hyderabad, and at Kakar in Larkana.

III. *Summer 1903:* (June to August 1903).

Summer Flights continued in Sind and were reported from all parts of Sind except Thar-Parkar during June and July, damaging mango and other trees, germinated rice seedlings and kharif crops such as *jowar* and *bajri*. In *Baluchistan*, swarms were reported from various parts of Mekran (Dasht, Kolwa, Tump, Nigwar and Panjgur), damaging date palms, jowar, lucerne and other crops. Several flights passed over Lasbela (Mango trees being damaged), Kachhi, and parts of Quetta-Pishin (Sanzala and Baghak in Toba Achakzai), Thal-Chotiali and Sibi. "Crawling" locusts were said to have been found on the high valleys of Toba Achakzai, indicating the occurrence of breeding.

In *Rajputana* the earliest record was that of a flight of yellow locusts on the 7th June at Shahgarh coming from Khairpur side. There were several further records in July in Jaisalmer area. Flights were recorded in the *United Provinces* during the third week of June in Aligarh and Banda districts. During the second week of July, swarms appeared in 8 districts including Benares, Azamgarh and Gorakhpur in the east.

By the end of June and the beginning of July, swarms passed over a portion of *Bihar* and *Chota Nagpur*. During June-July, flights would appear to have been active in Muzaffargarh, Monghyr, Bhagalpur, Sonthal Parganas, Hazaribagh, Palamau and Manbhoom districts of Bihar, and to have reached Birbhum district in the south and Jalpaiguri district in the north of *Bengal* Province.

As locusts are said to have been collected in August 1903 from Palanpur, swarms would appear to have reached the Western India States in July. In this connection, it may be mentioned that damage by locust swarms was reported from the end of June up to the end of August from the southern parts of Central India: Bhopawar, Indore, Dhar, Jobat, Jhabua and Barwani. These are evidently referable to the *Bombay Locust*, which was active in this area as well as in Panch Mahals, Gujarat and Khandesh in 1903.

Summer Breeding: Sind. Swarms were reported throughout August from the Thar-Parkar district, and were said to have come from the north presumably from Rajputana. As good rainfall had occurred in July all over the desert, it is likely that some breeding had taken place, but there are no records.

In *Baluchistan*, hoppers were noted in Barkhan tahsil, at Ranrkhan in August, but were said to have been destroyed by "Tiliar" birds (starlings). Hoppers were seen also at Chuharkot in September in the same tahsil.

Rajputana Jaisalmer records show that hoppers had been observed in Mohangarh, Tanot, Nokh, Lakha and Ramgarh during September-October. Since there was similar good rainfall in July in the Marwar and Bikaner areas, it is quite likely that breeding had occurred in many parts of these states. Indeed Pundit Suraj Prakash mentions having found a band of full grown hoppers in 1903 (August ?) near Jodhpur Railway Station.

Punjab. Swarms from the west entered Punjab in July and were found in many of the central and eastern districts. Summer breeding occurred only in three districts: Multan, Mianwali and Ferozepur.

On the whole, summer breeding does not appear to have been extensive in 1903.

IV. *Autumn* 1903: (September—November 1903)

Breeding. There was some breeding in Barkhan tahsil (Chuharkot) in September, but none elsewhere in Baluchistan. In *Rajputana* and the *Punjab,* hoppers were observable till the end of September.

Autumn Flights: Baluchistan. Several flights were seen during autumn in various parts of the province. Swarms were reported in Lasbela in October-November at Karachi, along the Jhau borders and in the Levy tracts, damaging jowar and mung crops. Damage was said to have been done to the crops of tribes in Kalat State, and also in parts of Mekran, especially in Dasht and Pasni. Flights were also observed in Duki, Barkhan and Musakhel tahsils of Loralai and in Vitakri and Kohlu tahsils of Sibi during November and December.

Sind. Locusts were found in most parts of the Desert areas of Thar-Parkar in August and September. It is possible that some breeding had occurred. From the last week of September, numerous swarms of locusts began to appear in the district, by which the fine kharif crops that had sprung up in the desert were so seriously threatened as to compel the cultivators to cut them prematurely.

There were numerous flights in all parts of Sind in October and November, which caused considerable damage to barani crops, throughout the Province and especially in Kohistan and other parts of Karachi. In December, locusts were reported only from Hyderabad and Karachi districts.

Punjab. Autumn flights were reported mostly from the southern and central parts of the Punjab during October-November: Lahore, Jhang, Montgomery, Amritsar, Ludhiana, Multan. Muzaffargarh, Dera Ghazi Khan, Ferozepur, Hissar, Gurgaon and Mianwali. There were no reports during December.

Rajputana. Several flights in Jaisalmer and Sirohi are recorded in September and October. In October and November, locust damage was reported from many parts of Rajputana, including Bikaner, Marwar Jaisalmer, Sirohi, Jaipur, Kishengarh, Ajmer and Karauli.

United Provinces. Damage by locusts was reported from Muttra and Agra in the early half of October.

Central India. Damage by swarms is recorded in Gwalior, Indore, Malwa, Bhopawar and Bundelkhand during the third week of October.

Central Provinces. Locusts were reported to be present in Seoni district in the third week of October and in Chhindwara district in the following week. They were recorded in Mandla and Chhindwara in the first week of November. During week ending 21st November, they were present in Akola and Buldana districts of Berar.

Bombay Presidency. In 1903, the situation in the northern parts of the Bombay Presidency was peculiar in that two species of locusts were active in this area. The Bombay Locusts advanced from the southern

district of Bombay north and north-east into Nasik, Khandesh, Baroda, Panch Mahals, Indore, Jhabua, Jobat and Barwani during May-June 1903. After breeding in parts of these areas, the new generation of the Bombay Locust began, according to Lefroy [1906]: "late in October 1903, to move from the Gujarat districts, generally north to south and from coast to inland. The swarms passed through Kaira, Baroda, Rajpipla, Broach and Surat into Ratnagiri and Kolaba and the adjoining hilly forest regions. By the end of November, only scattered swarms remained which disappeared in December."

On the other hand, the Desert Locust was present in Kaira in August, in Palanpur in September, and in Halar (Kathiawar) in October, as specimens collected from these places in the months specified were definitely identified as *Acridium peregrinum* (*Schistocerca gregaria*), as recorded in the Annual Report of the Department of Agriculture and Land Records, Bombay for 1902-1903. It is probable that, while the Bombay Locust was moving about in areas east of a line from Ahmedabad to Kaira during August and September, the Desert Locust was present in areas to the west of this line. In October, as the Bombay Locust began to retrace its steps back into the southern parts of Bombay, the desert locust was also gradually moving south into Broach, Surat, Khandesh and Nasik during November-December. According to Lefroy [1906] "*Acridium peregrinum* also appeared in Gujarat, after the swarms of the Bombay Locust had left. Kathiawar reported flights in November, and swarms were seen alighting at places along the coast, apparently after their flight over the Gulf of Cambay. They passed through Surat district early in December, compact swarms flying by day and visible far out to sea as they approached land."

Swarms of the Desert Locust had presumably appeared in Palanpur, Radhanpur, Viramgam and Rajkot areas from the breeding areas in south Rajputana and Thar in September and October, and had gradually advanced eastwards and southwards in November-December into Broach, Baroda and Surat districts.

At the same time, swarms had apparently reached Jamner area in east Khandesh by the end of November from the Akola and Buldana areas of Berar, where they were reported to have been present in the third week of November. During December, flights of the Desert Locust would appear to have spread over Khandesh and Nasik as far west as Peint.

In this connection, the movements of swarms south into Chhindwara would appear to have been facilitated by the prevalence of northerly winds in Central Provinces under the influence of a storm which crossed the Circars coast on the 30th October. Similarly, the westward movements of flights in Central Provinces into Akola and Buldana and thence into Khandesh, and perhaps into the Aurangabad district of Hyderabad, would appear to have been helped by the development of north-easterly, winds in connection with depressions off the Madras Coast.

Summary of Events in 1903

(1) Winter-spring rainfall was, on the whole, defective in south Persia and Oman, but spring rainfall was fairly good in Upper Iran, Upper Baluchistan and Punjab.

(2) Over-wintered locusts were found in Sind and parts of Punjab and Baluchistan.

(3) There was no spring breeding in Baluchistan (except in Toba Achakzai). In the Punjab, breeding occurred in nine districts in north and Central Punjab.

(4) Western migration commenced at the end of May and reached Bihar and Bengal by June-July.

(5) Except for heavy falls in July, the monsoon rainfall was rather defective. Breeding was restricted to three districts of the Punjab and parts of western Rajputana.

(6) Autumn flights reached Central India, the Central Provinces, north Bombay (Khandesh and Nasik) and the Gujarat districts. There were strong westward flights in October and November. The Bombay Locust was also active in north Bombay in autumn.

YEAR 1904

A. Weather Notes, 1904

I.—Winter-Spring Rainfall 1903-1904 (*in inches*)

1903-1904	Nov.	Dec.	Jan.	Feb.	Mar.	Apl.
Iran :						
Bushire	..	2·62	0·84	0·33	0·75	0·23
Jask	..	0·77	0·89	0·94	1·40	0·05
Meshed	0.21	0·75	0·77	3·26	4·44	0.45
East Arabia :						
Muscat	0.04	0·13	..	0·10	0·11	..
Behrein	..	0·15	0·25	0·16	0·86	0.10
Baluchistan :						
Queta	0.22	0·23	4·42	0·60	2·46	0·08
Chaman	.	0·15	1·93	0·92	2·38	0·24
Nushki	0.14	0·41	1·94	0·80	2·93	0·13
Mithri	..	..	..	0·15	4·00	..
Sind :						
Karachi	..	..	1·32	0·97	1·97	..
Punjab :						
Rawalpindi	..	1·05	4·70	0·04	4·87	0·39
Gujrat	..	0·15	4·31	..	4·54	0·11
Jullundur	..	0·45	1·05	0·25	5·40	0.07
Hissar	..	..	0·33	..	3·80	..
D. G Khan	..	0·06	1·18	..	2·07	..
N.W.P. Province :						
Peshawar	0.09	1·00	3.20	..	6·80	0·96
Bannu	..	0.43	1.10	..	6:04	0.04

Winter as well as spring rainfall was defective in south Persia and East Arabia. In Upper Persia and Punjab, rainfall was fairly high especially in January and March.

II.—Monsoon Rainfall 1904 (*in inches*)

1904	May	June	July	Aug.	Sept.
Sind :					
Karachi	..	..	..	..	..
Mithi	0.04	..	2.32	0.03	..
Chachsro	...	..	1.79	0·06	0.83

1904	May	June	July	Aug.	Sept.
Rajputana :					
Barmer	0·42	..	0·87	2·11	0·29
Jodhpur	0·40	1·23	1·58	0·89	1·84
Jaisalmer	0·70	0·21	..	0·05	..
Bikaner	0·05	1·09	0·43	1·43	2·68
Jaipur	0·63	1·22	7·70	0·91	1·50
Ajmer	1·37	2·07	4·09	6·84	0·30
Punjab :					
Rawalpindi	0·70	..	7·04	9·50	0·61
Gujrat	0·33	0·13	2·50	4·28	0·72
Jullundur	0·81	0·45	1·23	6·90	3·60
Hissar	0·19	1·23	1·17	6·44	2·23
D. G. Khan	..	..	..	..	0·21
N. W. F. Province :					
Peshawar	0·36	..	0·69	1·40	2·80
Bannu	0·22	..	1·67	1·50	0·51

The monsoon commenced late, and was more or less a failure in Sind, Western Rajputana and south-west Punjab. Rainfall was more or less normal in north Punjab and east Rajputana in July, August and September.

B. LOCUST DATA, 1904: (*vide* Pl. 4 Fig. 3)

I. *Winter* 1903-1904: (Dec. 1903 to Feb. 1904)

Except for a few locusts found on the *rabi* crops in Karachi and Thar-Parkar early in January, there are no reports of flights in Sind.

The swarms which spread into Ahmedabad, Surat, Nasik and Khandesh in December were being reported to be damaging crops in these areas till the last week of January. In Khandesh, damage to cotton and Jowar continued up to the 16th February. There are no records of locusts from other places.

II. *Spring* 1904: (March-May 1904).

In the *Punjab*, locusts are said to have appeared in parts of Lahore during week ending 22nd March. They were reported to have passed over Ferozepore during the second week of April without damaging crops, and some swarms were also observed in Multan in April. These locusts belonged presumably to the over-wintered brood which had been roused into activity by the general and fairly heavy rainfall of March. Apparently there was no oviposition.

In *Baluchistan*, locusts were said to have appeared in villages in Bhag niabat in Kachhi on the 24th May. "Small locusts"—presumably *hoppers*—are reported to have appeared at Chattar in Lehri niabat at the close of May. Breeding might have been possible in Kachhi, as there was heavy rainfall in March in that area. In Rakhni and Ranrkhan areas in Loralai, small "tiddis" are said to have appeared on crops. Possibly these were grasshoppers of the genus *Caloptenopsis*.

III. *Summer* 1904: (June-August 1904).

Summer Flights. The usual flights from the winter rain areas started at the end of May in Kachhi. Swarms passed through Chuharkot on the 8th June and Ranrkhan on the 11th in Loralai district. The first recorded

swarm in Jaisalmer was on the 18th June at Nokh from Bahawalpur passing south into Marwar and on the 25th at Shahgarh south to north, In Sind, the first record of flights was in the week ending 20th June in Karachi and Hyderabad. In the United Provinces, locusts were reported to have appeared in a tahsil of Cawnpore during week ending 18th June. These data would indicate that flights had been in progress in these areas much earlier than on the dates of record. Apparently several swarms had escaped notice over large areas.

During July, locusts were reported over Mekran, parts of Sibi and Loralai, over most parts of Sind and in United Provinces and Punjab. In the Punjab, swarms appeared in the Multan district in the 3rd week of July. In the United Provinces, swarms reached Aligarh, Hamirpur, Jalaun, Farrukhabad and Hardoi districts during July. Early in July, locusts were reported at Delhi (W.E. 2nd July) flying in an east to west direction, presumably under the influence of easterly winds and in the 3rd week of July in Hissar district. Damage to cotton and *chari* was reported from Montgomery district.

In August, numerous swarms were reported passing over parts of Loralai district and one over Lehri in Kachhi (23rd August flying east to west). On the 4th August swarms flew north to south over Nokh in Jaisalmer towards Marwar territory. There are no reports for Sind in August.

In the Punjab, swarms appeared during August in Delhi, Ambala, Lahore, Amritsar and Hoshiarpur districts. It is possible that the appearance of swarms in these districts had been due to the activity of easterly winds bringing them westwards from the United Provinces.

Summer Breeding. Although there was a fair amount of rainfall in July and August in many districts, no breeding was reported. In Sind and Rajputana, rainfall was too short to favour oviposition but, according to a report received by Raj Marwar, breeding occurred in August on the borders of Sind and Marwar.

IV. *Autumn* 1904; (September-November 1904).

Autumn Filghts: Sind & Baluchistan. A few flights were reported in Karachi and Loralai districts in September and October. Swarms of locusts were seen at Kanrach on the 20th September—apparently from Karachi area—but disappeared without damaging crops. A few flights also appeared in Welpat and Sheh in autumn and damaged the few crops raised.

Punjab. No reports of swarms after August.

Bihar. According to the Annual Report of the Bengal Department of Land Records and Agriculture for year ending 31st March 1905, flights were seen in September in parts of Saran and Champaran. They also appeared about the same time in Hazaribagh district at Kodarma, Chatra and Ganwan, causing damage to crops. It is presumed that these swarms had been derived from the flights visiting the United Provinces during June, July and August, and had been carried there by the westerlies that usually appear in September in these areas with the withdrawal of the monsoon.

There were no flights in Western India States and Gujarat and other parts of India during 1904. It may be mentioned here that the Bombay Locust had attained the peak of its development in 1904 and had reached as far as north as Malwa (23°N. Lat.) in Central India and had spread

over Dhar, Jhabua, Jobat, Indore, Nemawar and Alirajpur in July-August. It had also spread into the whole of Berar and the western districts of Central Provinces, during the monsoon period and had bred there. The new generation, produced in Berar and Central Provinces, left the area westwards in the direction of Bombay territory, after the development of north-easterly winds in November.

Summary of Events in 1904

(1) Winter-spring rainfall was defective in Iran and Oman but in Upper Persia, Upper Baluchistan and Punjab, fairly heavy rainfall occurred in January and March.

(2) There were few over-wintered locusts in the Indian areas and there was no spring breeding except in a few doubtful cases as in Kachhi.

(3) Western flights appeared at the end of May in Kachhi and in June in Sind and Rajputana and reached the United Provinces as far east as Cawnpore.

(4) Flights appeared in Punjab, Rajputana and United Provinces in August, but there was apparently no summer breeding, owing to defective monsoon rainfall except in a part of Marwar.

(5) Autumn flights were few and were observed in Sind and Baluchistan, and in Bihar in September.

YEAR 1905

A. Weather Notes, 1905

I.—*Winter-Spring Rainfall* 1904-1905 (*in inches*)

1904-1905	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Iran :						
Bushire	0·11	5·66	0·32	1·09	1·52	..
Jask	0·62	..	0·39	1·29	1·53	..
Meshed	2·35	0·79	1·11	0·09	1·60	0·85
East Arabia :						
Muscet	0·70	0·03	1·24	1·83	2·21	..
Bahrein	..	...	0·10	0·45	0·38	..
Baluchistan :						
Quetta	0·40	0·08	5·04	3·48	2·48	0·38
Chaman	0·15	0·02	3·62	1·78	1·69	..
Nushki	0·05	..	3·10	2·42	1·04	0.06
Kalat	0·40	..	3·60	2·14	2·18	0·84
Sind :						
Karachi	..	..	1·91	2·28	..	..
Punjab :						
Rajwalpindi	0·61	1·55	4·96	2·68	2·21	0·71
Gujrat	0·09	1·53	4·90	1·59	1·41	0·26
Jullundur	0·15	2·37	1·79	2·14	1·08	..
Hissar	0·06	0·85	1·21	2·10	0·25	..
D.G. Khan	0·03	0·21	1·24	0·09	0·15	..
N.W.F. Province :						
Peshawar	0.07	0.14	1·63	1.91	4·66	0.09
Bannu	0.49	0.04	2·48	0.97	2.99	0.26

Winter-spring rainfall in south Persia and Oman was rather poor except in February and March. Winter rain was poor, but spring rainfall was plentiful in Upper Baluchistan, Punjab and North West Frontier—in January, February and March.

II.—*Monsoon Rainfall* 1905 (*in inches*)

1905	May	June	July	Aug.	Sept.
Sind :					
Karachi	..	..	0·13	..	..
Mithi	..	..	5·01	..	1.50
Chachro	..	..	5·73	..	2.16
Rajputana :					
Barmer	..	..	2·21	..	0.86
Jodhpur	..	0·80	0·66	0·18	1.45
Jaisalmer	..	..	0·06	0·18	1.45
Bikaner	..	0·24	0·40	..	1.68
Jaipur	0·02	0·37	0·40	0·86	2.03
Ajmer	..	0.41	1·62	0.30	3·78
Punjab :					
Rawalpindi	0·72	0·35	5·60	3·75	4.26
Gujrat	0·22	0·60	6·24	2·55	6.36
Jullundur	..	0·22	2·99	1·74	2.54
Hissar	0·25	0·54	5·10	0·15	3.83
D.G. Khan	0·20	0·06	0·29	..	0.36
N. W.F. Province :					
Peshawar	1·83	..	0·18	0·67	0.92
Bannu	0·32	0·55	1·96	0·39	1.67

June was practically dry. In July, there was fairly good rainfall in the Punjab, as also in the desert talukas of Thar-Parkar and in Mallani, but very little in most parts of Rajputana. August was dry in N.W. India, except in the Punjab. There was a fair amount of precipitation in September in almost all parts of north west India except south Sind.

B. Locust Data 1905: (*vide* Pl. 42 Fig. 4)

I. *Winter* 1904-1905: (December 1904-February 1905).

No records on locust activities.

II. *Spring* 1905: (March-May 1905).

Baluchistan. Locusts were reported to have appeared near Pringabad and Mastung in Sarawan during the third week of April. Large swarms were said to have arrived near Nushki and to have begun laying eggs at the beginning of May. There was a violent duststorm on the 8th May, which drove some of the swarms away. On the 13th May, locusts appeared at Pringabad and apparently laid eggs on sand heaps, which hatched out in the second week of June.

There were no data for other areas.

III. *Summer* 1905: (June-August 1905).

Spring Breeding. Apparently there was breeding in May in Chagai district (Nushki) and the adults of the new generation began to fly towards Sarawan during June.

Breeding also occurred in the Pringabad areas—of Sarawan and steps were taken to destroy the hoppers.

Summer Flights. The first flights in *Sind* were signalled during week ending 28th June, in Upper Sind Frontier (on 21st June at Shadadkot), in Hyderabad (Shahdadpur, Nasrat and Sakrand, passing south), in Larkana (Mehar and Kakar), and in Sukkur (Mirpur). In the *Punjab,* the first report was from Dera Ghazi Khan on 16th June. In *Baluchistan,* swarms appeared on 24th June in Lasbela territory from a north-westerly direction and passed on south-east, and in Pringabad locusts from Nushki side damaged potato crops on the 29th June, and other swarms passed over Guru on the 30th. Locusts were reported during the first week of July in Dasht ilaqa in Mekran, and about the middle of the month in Nasirabad tahsil in Sibi district. During the third week of July, swarms appeared in Hissar in Punjab and were reported from Agra on the 20th July.

In the *Rajputana* area, the first report of swarms was recorded on the 15th September at Bap. This may be correlated with the circumstance that in Jaisalmer area there was practically no rainfall till September. Except in parts of Thar, where good falls of rain were received during July there was little rainfall all over the Sind-Rajputana area during June, July and August, though in September there was general precipitation all over the desert. It is to be presumed that the swarms from Sind and Baluchistan had passed over Rajputana as they usually do, but owing to the prevailing conditions of extreme drought had not alighted anywhere except for short halts and had not been reported as there were no crops on the ground liable to damage.

Summer Breeding. In Sind there were numerous reports of flights in July and August, and during *August,* there were reports of the presence of young locusts (hoppers) in Diplo and other talukas of the desert area of Thar-Parkar, damaging grass and kharif crops. Presumably oviposition had followed the fairly heavy falls of rain in July in these areas. It is possible that light breeding had also occurred in the neighbouring Mallani area in Marwar, where also some rain had fallen in July.

In the Punjab, a few flights are recorded in August in Ferozepur and Gurgaon districts, but none in the United Provinces. In Bihar, however, a flight was reported to have visited the Palamau district in August, damaging the maize crop. Presumably, westerly winds prevailed in the southern parts of the United Provinces and in the Bundelkhand and Baghelkhand tracts of Central India in August in view of the general drought.

IV. *Autumn* 1905: (September-November 1905).

Autumn Breeding. The following is an extract from the Jodhpur State Administration Report for the year ending 31st March 1906: 'April and May were almost rainless. In June, the fall was either blank or meagre. In July except in two parganas, the rains were fitful and insufficient. August went almost dry. A serious deficiency in rainfall was fortunately relieved by the welcome showers of the second week of September, caused by the cyclonic storm which passed over the State. Jalore registered the highest fall of 11·20'. The following four months were rainless.

Locusts. Some slight damage was done in November 1905 to the standing fodder crop by the young locust larvae that appeared in large

numbers in 15 Parganas. Arrangements for their destruction were made by employing hired labour at famine rates.

Since similar good rainfall was registered in other parts of Rajputana, it should be considered likely that breeding had occurred wherever locusts were present at the time of rainfall. During October, damage by locusts was reported in the Season Reports of the Gazette of India in the areas of Marwar, Mewar and Ajmer-Merwara from the last week of October up to end of November. It is probable that, as in Marwar, damage by locusts is really referable to *hopper damage* in Mewar and Ajmer-Merwara also. In Jaisalmer, oviposition would appear to have occurred in Dewa and Barawa-Bueli Parganas.

The adults of the new generation probably appeared by the later half of November.

Autumn Flights: *Baluchistan.* During September, swarms frequently appeared in Saruna in Jhalawan and damaged trees and grass. In October, flights were seen in Lasbela in the neighbourhood of Bela, Sheh and Liari; they also appeared in the Drug, Musakhel and Barkhan areas of Loralai. In November, several flights were reported from Kachhi and from Sibi and Loralai districts, and in December from Loralai (Duki, Barkhan, Musakhel and Sinjawi), Zhob (Fort Sandeman) and Jhalawan (Saruna valley).

Sind. There were numerous flights in September, October, November and December in all districts of Sind.

Punjab. On the 14th September 1905, swarms are said to have appeared in Rewari and deposited eggs, and hoppers were found appearing by the 27th September and beginning to damage crops. Swarms appeared in Gurgaon, Lyallpur and Dera Ghazi Khan districts in September. Several flights were also reported mostly from the southern and western districts of the Punjab: Rohtak, Gurgaon, Delhi, Dera Ghazi Khan, Muzaffargarh and Mianwali, causing considerable damage to crops, In the 3rd week of October, locusts appeared in the Marwat tahsil of Bannu district in N.W. Frontier passing east to west.

Rajputana. Several flights were recorded as active in the autumn months in Jaisalmer, Sirohi, Marwar, Mewar, Jaipur and Ajmer-Merwara.

In the *United Provinces,* slight damage to crops by locusts was reported from Bara Banki, Rae Bareli and Jaunpur during the 3rd week of September. Hoppers were said to have attacked cotton and bajri in Agra on 20th September 1905 and at Etmadpur on 4th October 1905. In December, locusts were said to be causing slight injury to crops in Bulandshahr, Agra, Farrukhabad and Cawnpore.

Central Provinces. During the first three weeks of September, flights were reported in Saugor, Damoh, Jubbulpore and Narsinghpur districts. The general direction would appear to have been north-west to south-east.

Western Indian States. On the 28th September, 1905, there is a record of a flight from Palanpur State into Sirohi. During October, flights appeared in Tharad, Roh and Dhanera in Palanpur agency and in December in Varahi State (Palanpur) and Rapar and Khadir talukas in Cutch.

Central India. Locusts were reported from parts of Dhar State in the 2nd week of October.

Summary of Events in 1905

(1) Rainfall poor in winter in south Iran and Oman, but fair in the spring months. Spring rainfall in Upper Baluchistan and Punjab fairly good.

(2) There were no over-wintered locusts in Baluchistan or Punjab. Yellow swarms appeared from south Persia in Sarawan and Chagai towards the end of April and laid eggs in these areas in May. Possibly similar breeding occurred in Persian and Afghan territory.

(3) Western flights appeared by middle of June in Punjab, North Baluchistan, Lasbela and Sind, and reached the United Provinces (Agra) in July. Some of these were reported from as far east as Bihar in September.

(4) Summer breeding occurred to a certain extent in the Thar area of Sind (good rain in July) in August-September. There was no breeding elsewhere in the Sind-Rajputana desert owing to the absence of rainfall. With the fall of fairly good general rain in Rajputana area in September (II week), widespread oviposition occurred in Marwar and possibly also in Ajmer and Jaipur, bringing about autumn breeding.

(5) Autumn flights occurred in Baluchistan, Sind, Punjab and Rajputana. They reached United Provinces, Central Provinces and Central India to the east and Palanpur and Cutch to the south.

YEAR 1906

A. Weather Notes, 1906

I.—*Winter-Spring Rainfall* 1905-1906 (*in inches*)

1905-1906	May	Dec.	Jan.	Feb.	Mar.	Apr.
Iran.						
Bushire	1·10	1·35	3·66	1·98	0·03	0·56
Jask	0·88	3·37	1·25	1·88	0·38	..
Meshed	0·11	1·00	1·03	0·78	3·16	2·90
Ispahan	0·05	0·45	1·66	1·06	0·34	1·36
Arabia.						
Muscat	0·21	0·09	0·60	1·31	1·45	..
Bahrein	..	0·75	0·32	1·22	1·30	..
Baluchistan.						
Quetta	0·07	3·60	0·73	3·87	4·36	0·25
Chaman	0·05	5·55	0·94	4·07	2·79	0·18
Nushki	..	2·63	0·50	3·23	1·16	0·11
Mithri	..	0·36	..	2·79	0·91	..
Loralai	..	1·02	0·05	3·45	2·27	0·61
Sind.						
Karachi	..	0·18	0·10	3·34	0·22	..
Punjab.						
Rawalpindi	..	3·02	0·53	6·68	4·34	0·80
Mianwali	..	1·48	..	3·40	1·09	0·11
Jullundur	..	0·44	0·12	3·66	1·44	0·05
Hissar	..	0·17	..	1·93	1·04	..
Gurgaon	..	..	0·22	1·90	1·34	0·11
N. W. F. Province.						
Peshawar	..	2·34	..	3·97	1·06	0·71
Bannu	0·01	1·50	0·03	3·41	1·51	0·53

Winter-spring rainfall was fairly abundant in south Persia, but poor in Oman. Spring rainfall was fair in south Persia and Oman and fairly good in Upper Persia. Both winter and spring rainfall was fairly heavy—especially in December, February and March—in Upper Baluchistan and Punjab and N. W. Frontier.

II.—*Monsoon Rainfall* 1906 (*in inches*)

1906	May	June	July	Aug.	Sept.
Sind.					
Karachi	..	1·95	..	3·13	0·45
Mithi	..	0·85	1·97	3·36	6·98
Chachro	..	1·79	0·95	6·29	1·93
Rajputana.					
Barmer	..	..	2·28	3·47	3·74
Jodhpur	0·06	0·11	3·92	1·84	3·95
Jaisalmer	..	0·16	1·08	4·76	4·10
Bikaner	..	0·72	1·80	3·85	3·11
Jaipur	0·21	1·12	5·62	1·39	2·94
Ajmer	..	3·68	7·45	3·35	3·11
Punjab.					
Mianwali	0·15	1·47	1·77	3·19	0·85
Rawalpindi	0·47	2·88	8·20	16·01	11·30
Gujrat	0·05	0·73	4·24	5·94	5·12
Jullundur	..	1·17	4·81	12·13	8·98
Hissar	0·92	1·57	1·77	3·36	3·33
Gurgaon	0·18	2·93	7·02	3·13	13·76
D. G. Khan	0·11	1·02	..	1·06	..
N. W. F. Province.					
Peshawar	0·39	0·94	0·71	1·37	0·63
Bannu	..	..	..	9·24	1·02

The monsoon began early with a fair amount of rainfall in June. Rainfall in July was fair on the whole; fairly heavy rainfall in August and fairly good precipitation in September in most places. The monsoon was heavy, on the whole, but did not give much rainfall in East Baluchistan.

B. LOCUST DATA, 1906.—(*Vide* Plate 53, fig. 1)

I. *Winter* 1905-1906: (Dec. 1905—Feb. 1906)

Baluchistan. Locusts were found in Drug circle of Musakhel tahsil of Loralai district during January and February.

Sind. Swarms were found all over Sind in January and the first week of February. They disappeared after the occurrence of heavy rainfall about the middle of February.

Punjab. Locust swarms were active in January and February in Mianwali, Shahpur, Attock, Multan, Dera Ghazi Khan, Lahore, Gujranwala, Hissar, Gurgaon and Rohtak.

Rajputana. Locusts were found in two districts of Karauli in January.

N.W. Frontier Province. Swarms appeared in Dera Ismail Khan and Bannu districts.

Western India States. Slight damage to spring crops by locusts was reported in Panch Mahals in February.

II. *Spring* 1906: (March—May 1906)

It was reported that locusts had appeared near Panjgur and the neighbourhood of Barsoli in Mekran at the close of March and the beginning of April and damaged grass and cultivation. About this time (probably middle of April) crops in Kharan were said to have been totally destroyed. At the beginning of May (4th May), locusts are said to have appeared in Gandhawa and Mirpur (and probably also Bhag) niabats from south west (presumably from Jhalawan) and laid eggs there. Hoppers were found in the 3rd week of May damaging crops in these areas. Swarms of locusts also passed over Dadhar (Kachhi) on the 10th May, over Barkhan (Loralai) on the 11th May, over Kalat, Neemargh and Kishingi (Sarawan) on or about the 14th, over Rakhni (Loralai) on the 21st and over Quetta on the 24th flying south-west to north-east, and over Dadhar (Kachhi) and Mastung (Sarawan) on the same date.

In *Sind,* locusts first appeared in large numbers on the 10th and the 12th May in parts of Kotri taluka (Karachi) and about the same time at Johi (Larkana) and at Nasrat and Hyderabad (Hyderabad). Several other swarms were reported during the rest of the month in the above districts.

In the *Punjab,* locusts laid eggs in Mianwali, Attock and Montgomery and hoppers hatched out in April in these areas and were destroyed as far as possible. In May, locust flights were reported from Shahpur, Mianwali, Attock, Jhelum, Gujranwala, Amritsar (north to south) and Karnal districts. In *N.W. Frontier Province,* locusts appeared in Bannu district during week ending 19th May and passed on to the north. There is little doubt that many of the swarms noted in north Punjab and in Bannu were connected with the wave of migration noted in Quetta, Loralai, Sarawan and Kachhi during the early part of May.

In the *United Provinces,* locusts were said to have been present in Tehri State in Garhwal during April—apparently some over-wintered forms.

III. *Summer* 1906: (June—August 1906)

Summer Flights from the West. The flights which commenced early in May in Baluchistan, Sind and the Punjab, continued in June and July in all these areas. As May and the early part of June were rainless, swarms would appear to have advanced eastward at a rapid pace, and numerous flights were observed in Bihar in the latter part of June.

Central Provinces. During the first week of June, swarms were reported from Damoh (passing east to west); in the second week, locusts are said to have passed over Narsinghpur and Balaghat, and in the third week over Seoni, Hoshangabad, Balaghat and Bhandara. Locusts were also observed in Mandla district in the first week of July.

Bihar. Swarms are said to have passed over Pusa Estate (Muzaffarpur district) on the 18th June. According to the administration Report of the Department of Agriculture in Bengal for the year ending 30th June 1907, locusts appeared in June in all districts of the Patna Division except Patna (Saran, Champaran, Shahabad and Muzaffarpur), casusing damage to crops in Buxar, Siwan, Samastipur, Champaran and Bettiah areas. On the 29th June, a swarm was reported at Sitamarhi on the Nepal borders, and as on the 2nd July a flight was reported to have passed over the Nepal valley from the south-east, it is evident that the easterly currents of the Bay monsoon were active at this time in carrying the swarms west-wards into the United Provinces, Nepal and the Punjab. Flights were

also reported from the Godda area of Santhal Paraganas and from the Monghyr district during June.

Western India States. Swarms were reported to have passed over Deodar in Palanpur area and over Danta, Sudasna and Gadhawada in Mahikantha areas. Flights are said to have visited Porbandhar area in Kathiawar in June from Rajputana, having arrived from the sea, but the locusts were reported to have been found in such an exhausted condition that they were rapidly destroyed by birds.

United Provinces. There are only two records of locust damage, of which one was in the early part of July from Farukhabad district and the other in the last week of July from Almora and Garhwal. Apparently, movements of locusts had not been recorded in June, through they had doubtless taken place at least in the south of the Province.

It is thus seen that western flights reached as far east as Godda (87°E. Long) in Bihar by June.

Baluchistan. Locusts were said to have done considerable damage to the jowar crop in Kej area in June and July. There was similar damage to the *Chatri* crops in June and July in many parts of Kachhi; and considerable damage was reported to green crops in Lasbela (Levy tracts, Ormara, Welpat and Sheh). At Kalat the Melon crop was almost destroyed by locusts in June. It is reported that swarms visiting Kharan in summer caused considerable damage to kharif crops. Several flights passed over parts of Loralai (Duki, Sinjawai, Barkhan, Mori and Loralai), and in Jhalawar considerable damage was done to crops and gardens at Khuzdar and Ferozabad in the last week of July.

Rajputana. The first record of a swarm in Rajputana is from Mauri village in Siwana pargana on 14th June. A second swarm was reported from Mayajlar in Jaisalmer on the 26th June, and numerous flights from many parts of Rajputana during July and August.

Sind. Numerous swarms were active in almost all parts of the province between June and August.

Punjab. Large flights appeared in July and August in Mianwali, Shahpur, Attock, Lahore, Gujranwala, Amritsar, Ambala, Simla, Hissar, Gurgaon and Rohtak. It would appear that many of these swarms had been carried westwards from the United Provinces and Bihar by the easterly winds of the Bay monsoon. *N.W.F. Province*: Swarms appeared in July-August in Dera Ismail Khan and Bannu districts.

Summer Breeding. During July, August and September the distribution of rainfall was very favourable for the occurrence of wide-spread breeding in the Sind-Rajputana desert and in the Punjab. As regards Sind, there is no record of oviposition or the occurrence of hoppers in the desert areas of Thar-Parkar district. Since wide-spread breeding is recorded in Marwar under very similar conditions, breeding is quite likely to have occurred.

Rajputana: Marwar. There are records of the occurrence of swarms and *oviposition* in July in the following Paraganas: Pali, Jetaran, Bali, Desuri, Sojat, Parbatsar, Jodhpur, Sheo and Jalore. Eggs were also laid in Ajmer territory. In August, breeding was noted also in Phalodi, Siwana, Didwana and Nagaur and parts of Mallani. According to an office note of the Marwar Revenue Department Files: "In 1906, locusts showed an abnormality in respect of their breeding grounds by extending unusually deep into the eastern and northern districts up to the foot of the Aravali Hills, where they settled on the sandy banks and beds of the

numerous stream emerging from the Aravalis, for egg-laying. Their breeding grounds in August-October 1906 were practically the whole of Marwar along with the neighbouring States and British territory."

In Jaisalmer, egg-laying occurred in Nokh, Mohangarh, Nachna and Ramgarh, mostly cases of late breeding owing to the occurrence of late rainfall in Jaisalmer.

As to Bikaner, no records are available, but from Marwar records, it is evident that breeding had occurred in Sujangarh and Bikaner tahsils along the Marwar borders. As rainfall was satisfactory, there is little doubt that egg-laying had taken place in many parts of Bikaner.

From the season reports recorded in the Gazette of India for 1906, there are grounds consider that breeding had occurred also in Karauli, Tonk, Shahpur, Kishengarh, Jaipur, Dholpur and Ajmer-Merwara.

United Provinces. Presence of hoppers at the end of July at Aghai Chattar Tahsil in Muttra District was reported to the Imperial Entomologist, Pusa.

Punjab. Early breeding occurred in July-August in Rohtak and Gurgaon districts.

IV. *Autumn* 1906: (September-November 1906)

Late Summer or Autumn Breeding: Rajputana. As already mentioned, late breeding occurred in parts of Jaisalmer, hoppers being found till the end of October. It is probable late breeding occurred also in Ajmer, Merwar, Jaipur and other areas.

Punjab. As a result of heavy rainfall in August and September in many parts of the Punjab, swarms arriving from east Punjab and the United Provinces were, presumably, responsible for the breeding that took place in September-October in Mianwali, Shahpur, Sialkot, Gujranwala, Lahore, Lyallpur. Amritsar, Jullundur, Ludhiana, Ferozpur and Gurgaon. Hoppers were still to be found in November in parts of these districts. It may be noted that there was no breeding in Dera Ghazi Khan, Multan, Muzaffargarh and Hissar areas, which may be explained by the fact that in these areas rainfall was low in August-September.

Autumn Flights: *Baluchistan*: *Lasbela State.* Swarms from Sind passed over the State at Welpat and elsewhere on the 12th and 13th October and later on in December when they caused considerable damage to crops.

Loralai. Several swarms visited Musakhel, Duki and Barkhan areas, evidently coming from the Punjab. *Sarawan*: According to the report of the Mustaufi of Mustung, swarms of locusts visited Mastung from the Shorawak side (north-west) on the 17th and the 18th November and, after damaging wheat crops, vegetables and trees, passed on towards Sibi—a direction rather unusual at this period of the year.

Sind. There were numerous flights in all parts of Sind during the autumn months often causing much damage to crops. In December swarms were reported from Hyderabad, Karachi, Larkana and Tharparkar.

Rajputana. Several flights occurred all over Rajputana including Mewar, Tonk, Kishengarh, Jaipur and Ajmer.

Punjab. Numerous flights were seen in many parts of the province during November-December.

N.W.F. Province. Several flights were reported from the tahsils of Dera Ismail Khan during October, November and December.

Western India States. Swarms appeared in September in Panch Mahals (Godhra), and Cutch (Lakhput and Khavda). In November and December, several flights were recorded in Cutch (Mandvi, Mundra, Anjar, Abdasa, Nakhtarana etc.), in Kathiawar (Halar, Jhalawad, Sorath, Jasdan, Porbandar, Limbdi, Wankaner, Junagarh, Gohilwad etc.), in Palanpur Agency (Vada), in Mahikantha (Mohanpur, Idar, Rupar etc.) and in Ahmedabad district (Prantij and Modasa talukas), causing damage to jowar and wheat. Lunawada State was visited by locusts at the end of December (29-30-xii-1906).

United Provinces. Records of swarm movements in the province are available only from 17th November, and there are reports of damage by locusts from Aligarh, Meerut, Bulandshahr and Garhwal during November and December.

Nepal. A flight of locusts was reported to have passed over the Nepal valley on the 8th October 1906 in a north-easterly direction, apparently from the United Provinces.

Central Provinces. During week ending 13th October, locusts passed over Etawa in Saugor district into Bhopal territory. Reports of appearance of locusts in Basim and Buldana areas in Berar towards the close of October are obviously referable to the Bombay Locust (*Patanga succincta*).

Central India. Damage by locusts was reported from parts of Gwalior during September and from parts of Gwalior, Bhopawar and Indore during October and November.

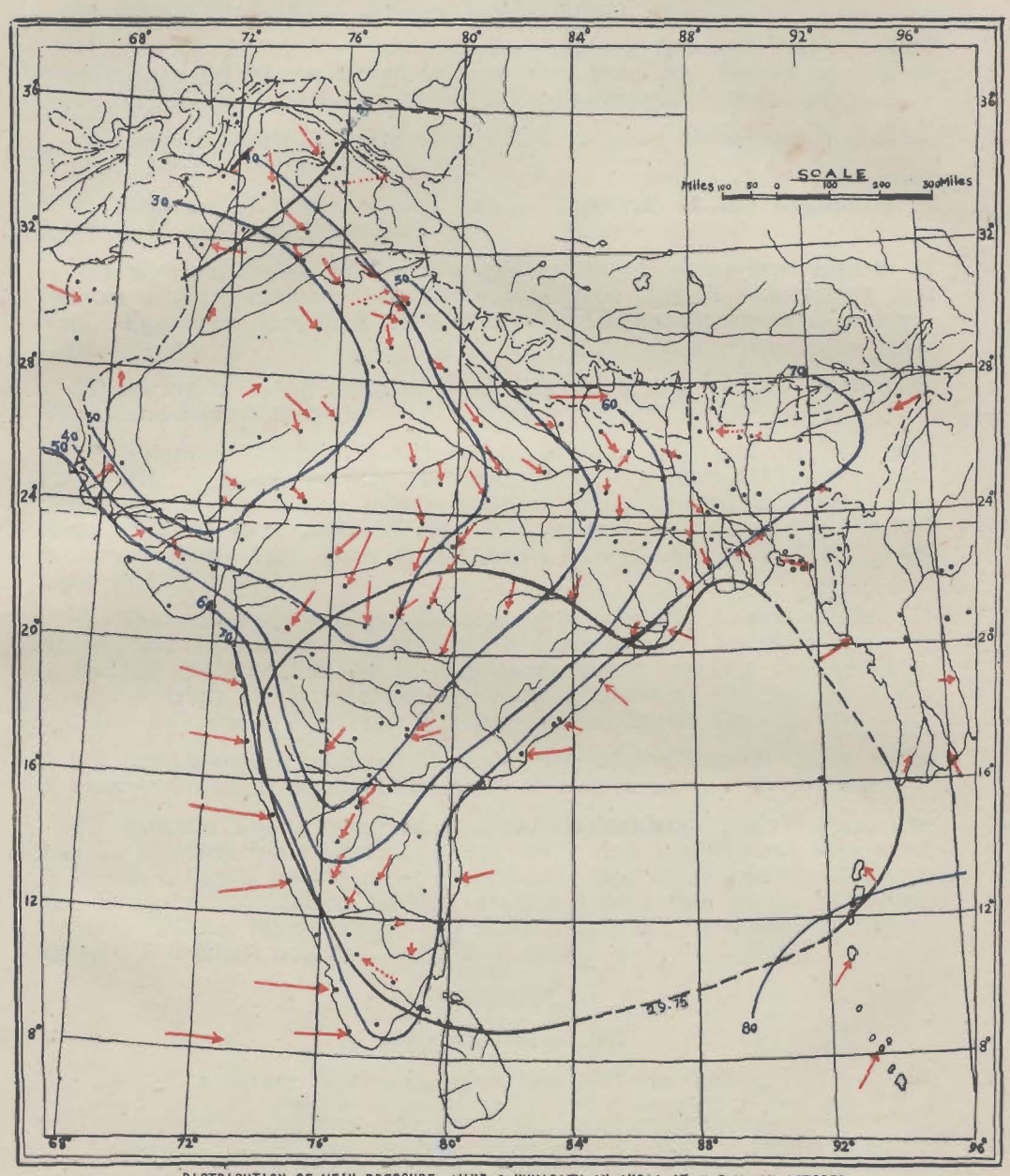
Hyderabad State. Locusts were reported to have appeared in two talukas of Osmanabad district (presumably, the locust in question was *Patanga succincta*).

Bihar, Bengal and Assam. In *Bihar*, swarms appeared in the first week of October in the Bhagalpur, Purnea, and Monghyr districts of Bihar division and in the Hazaribagh, Palamau and Ranchi districts of Chota Nagpur division, causing some damage to crops. In week ending 27th October, flights were reported from Champaran district also.

In *Bengal*, flights appeared in the second week of October and passed through Hooghly, Jessore and 24-Parganas districts; and in the third week, flights were reported from Rajshahi, Pabna, Mymensingh (Kishorganj), Nadia and Dinajpur districts.

In *Assam*, they were reported from Goalpara district and the Khasi and Jaintia Hills, where they damaged paddy crops to some extent. There were apparently comparatively few flights in November in Bihar and Bengal. Towards the middle of December, a flight of locusts is reported to have passed through Balasore in Orissa.

An examination of the weather data has shown that from the 30th September to 8th October, strong westerlies prevailed in the United Provinces and Central Provinces and Bihar, which were favourable for the spread of swarms towards Bihar and Bengal. In the second week, northerlies prevailed in Bengal and carried swarms into Hooghly, Jessore and 24-Parganas and during the rest of October there were only light westerlies that helped in the spread of swarms into north Bengal and Assam.



DISTRIBUTION OF MEAN PRESSURE, WIND & HUMIDITY IN INDIA AT 4 P.M. IN OCTOBER

(AFTER CLIMATOLOGICAL ATLAS OF INDIA)

It is thus seen that autum flights reached as far east as Khasi and Jaintia Hills (90°E. Long.) during 1906, though they did not spread southwards from the Central Provinces.

Summary of Events in 1906.—(Plate 53, fig. 1)

(1) Spring rainfall was fairly good in south Persia and Oman so that breeding should be considered to have been possible. Winter as well as spring rainfall was fairly heavy in Upper Baluchistan and Punjab.

(2) Over-wintering locusts were found in parts of Baluchistan, Sind, Punjab and Panch Mahals.

(3) Swarms of over-wintered locusts appeared at the beginning of April in Mekran and Kharan.

(4) Western flights of the new generation of spring-bred locusts of Persian origin commenced at the beginning of May in Baluchistan and Sind. Eggs were laid in Kachhi in May and breeding occurred in May-June.

(5) Spring breeding occurred in 3 districts of the Punjab (Mianwali, Attock and Montgomery).

(6) Summer migration which began in May continued in June and July. Flights passed rapidly over Rajputana, the United Provinces and Central India into Bihar, where swarms were observed in several districts. Flights were reported also from several districts of the Central Provinces. One flight entered the Nepal valley from Sitamarhi, flying south-east to north-east.

(7) The monsoon was satisfactory, with specially heavy rainfall in August and September. In the Punjab, early summer breeding occurred in Rohtak and Gurgaon and in Rajasthan, heavy breeding took place in several districts of Marwar, especially those adjoining the Aravali Hills, and probably also in Jaisalmer, Bikaner, Ajmer, Jaipur, Garauli, etc.

(8) Late breeding occurred in 11 districts of the Punjab in the wake of heavy rainfall in August-September, as also in parts of Rajputana.

(9) Autumn flights occurred in Sind, Baluchistan and Punjab, and also in Western India States, Central India and the Central Provinces. In October, flights passed rapidly eastwards into Bihar (Saran, Champaran, Shahabad, Monghyr, Santhal Parganas etc.) into Bengal (Jessore, Hooghly, Pabna, Mymensingh, and Dinajpur) and into Assam (Goalpara district) and Khasi and Jaintia Hills.

YEAR 1907.

A. Weather Notes 1907

I. *Winter-Spring Rainfall* 1906-1907 (*in inches*)

1906-1907	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Iran.						
Bushire . . .	2.57	0.25	0.37	4.76	0.22	0.61
Jask . . .	0.02	1.13	0.01	2.09	..	0.26
Meshed . . .	0.25	2.35	0.59	0.63	2.11	3.94
Ispahan . . .	1.49	0.40	..	2.19	1.36	0.49

1904-1905	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Arabia						
Muscat	..	1·57	0·23	3·12	..	0·87
Bahrein	0·04	..	..	1·87	..	0·26
Baluchistan						
Quetta	0·44	0·08	0 04	2·57	2·21	1·93
Chama	0·02	0·65	0·03	3·97	0·48	0.08
Nushki	0·04	0·14	..	4·39	0·29	0.63
Loralai	0·05	0·30	..	2·91	1·01	0.33
Sind						
Karachi	..	..	..	2·39	0·09	0.09
Punjab						
Rawalpindi	..	1·07	4·14	4·54	4·41	2.82
Mianwali	..	0·15	0·08	1·61	1·20	1.65
Gujrat	..	1·43	0·91	4·31	3·31	7·83
Jullundur	..	1·85	1·77	6·78	2·53	2·30
Hissar	..	..	..	2·69	0·54	2.14
D.G. Khan	..	0·95	..	0·28	0·13	1.12
N.W.F. Province.						
Peshawar	..	1·21	1·36	2·18	1·52	3·44
Bannu	..	1·78	0·11	2·42	2·12	1·69

There was fairly satisfactory winter and spring rainfall in south Persia and Oman in December and February. Spring rainfall was fairly high in Upper Baluchistan and the Punjab, especially in February.

II.—*Monsoon Rainfall* 1907 (*in inches*)

1907	May	June	July	Aug.	Sept.
Sind					
Karachi	..	3·15	0·14	3·83	0·04
Mithi	..	0·28	3·16	5·86	..
Chachro	..	0·29	3·59	5·41	..
Rajputana					
Barmer	0·34	0·45	3·80	12·47	..
Jodhpur	0·23	0·04	1·70	8·07	..
Jaisalmer	0·08	0·32	2·15	5·32	..
Bikaner	0·42	0·87	5·89	11·46	..
Jaipur	0·72	0·54	5·49	7·42	..
Ajmer	0·57	0·10	2·28	8·92	..
Punjab.					
Rawalpindi	1·32	4·37	3·25	5·39	..
Mianwali	0·22	1·35	0·98	2·92	..
Gujrat	0·76	2·05	2·41	6·35	..
Jullundur	0·15	0·47	2·22	8·01	..
Hissar	1·29	1·99	8·91	6·06	..
Gurgaon	0·38	0·75	1·96	6·60	..
N.W.F. Province					
Peshawar	0·12	0·06	1·50	1·25	..
Bannu	0·02	1·99	0·39	4·22	..

The monsoon began rather feebly in June, and in July was confined till the 20th to north-east India, but a fair amount of rainfall occurred

during the last week. Fairly wide-spread and good rainfall occurred in August. There was little or no rainfall in September in North West India.

B. LOCUST DATA 1907.—(*vide* Plate 53, fig. 2)

I. *Winter* 1906-1907.—(Dec. 1906—Feb. 1907).

Baluchistan.—Swarms were reported to be active in January and February in Loralai, Sibi, Sarawan and Kachhi areas. In Loralai district flights would appear to have come from the east (Punjab plains) in Barkhan and Musakhel, and in Duki and Thal areas from the south. In Sibi district, considerable damage is said to have been done all over the district. Presumably the locusts found in winter in Upper Baluchistan were derived from the swarms that were present in the plains of Punjab and Sind at the end of the autumn of 1906.

Sind.—Flights were reported from all parts of Sind during January and February.

Punjab.—Locusts were reported from Mianwali, Jhelum, Attock, Rawalpindi, Gujrat, Gujranwala and Sialkot in the north; from Lyallpur, Montgomery, Amritsar and Jhang in the centre; from Jullundur, Ambala, Karnal and Rohtak in the east and from Multan, Muzaffargarh and Dera Ghazi Khan in the south-west of the province.

North West Frontier Province.—Swarms were found in Bannu and Dera Ismail Khan districts.

Western India States.—Flights were said to have been damaging winter crops in parts of Kathiawar, in Mahikantha and in Ahmedabad and Kaira districts of Gujarat.

II.—*Spring* 1907.—(March—May 1907).

Baluchistan.—Swarms were reported in parts of Loralai and Sibi and in Karachi areas.

Spring Breeding.—Towards the end of April, hoppers were found in Loralai district between Duki and Baghao, and in Wahar and Mekhtar Circles. In the last week of May, hoppers are said to have been found in Shadozai and Musakhel tahsils. Considerable damage to rabi crops is said to have been caused in Kharan, and it is possible that breeding had occurred in Kharan and Chagai as there was good spring rainfall in February.

In May, swarms of red locusts are said to have appeared in Lahri, Gandhawa and Bhag niabats of Kachhi and caused damage to kharif crops and melons.

Sind.—There were no reports of flights after the 12th March in Karachi district.

Punjab.—Swarms were reported from almost all the districts of the Punjab during March and April. *Spring Breeding* occurred in the districts of Mianwali, Shahpur, Jhelum, Rawalpindi, Jhang and Lyallpur.

N.W.F. Province.—Breeding occurred in March, April and May in the Dera Ismail Khan, Peshawar and Bannu districts.

In both *Punjab* and *N.W.F. Province*, flights of the new generation commenced in May, and numerous flights were reported during the last two weeks of May from the *Kashmir* State (from Jammu, Riasi, Mirpur and Ramnagar districts), presumably coming from Jhelum, Gujrat and Rawalpindi districts of Punjab.

Bengal.—In April and May 1907, locusts are reported to have appeared in parts of the Malda district of Bengal, where they caused some damage to paddy crops. Presumably these were remnants of flights that were reported in Bihar and Bengal during October-November, 1906.

III.—*Summer* 1907.—(June—August 1907).

Baluchistan.—The first report of swarms from the west was that of the 2nd June when locusts from the west (Chagai ?) visited Sar-i-ab in Sarawan. There were several reports of flights in the Loralai district on 8th, 10th, 11th, 19th, 23rd and 30th, in which the direction of the flight was often east to west. A flight on the 11th passed over Quetta-Pishin and Toba in a northerly direction and several swarms passed over Zhob district causing damage to crops. There were further flights in Loralai and Kachhi in July and August. In *Lasbela,* there was damage by locusts to jowar and pulses in August.

Sind.—The first report of a flight was during the third week of June in the Upper Sind Frontier in Jacobabad and Thul talukas. Several swarms visited many parts of Sind during July, and apparently passed into Rajputana.

Punjab.—There were numerous flights all over Punjab in June but most of them were apparently swarms bred in N.W.F. Province and north Punjab. Some of them visited several parts of *Kashmir* State in the Jammu, Riasi, Mirpur and Kathua areas, causing much injury to cotton and melons.

United Provinces.—The first record of locusts is for the second week of June, when swarms were reported to have passed through Nainital, Bulandshahr and Fyzabad. The circumstance that swarms had reached as far east as Fyzabad (82°E. Long.) would indicate that locust movements eastwards or south-eastwards from the Punjab areas were already in progress for some time. During the next three weeks (during which easterly winds were prevalent in general in the province) swarms were reported only from the northern districts,—Dehra Dun, Hehri, Garhwal and Almora. During the week ending 13th July, locust damage was recorded in Benares, Jaunpur, Ballia and Mirzapur. After the 20th July, flights were recorded only from Aligarh and Dehra Dun till the end of August, after which there were no further records of locusts for 1907.

Bihar and Bengal.—During the week ending 13th July, flights were reported from Gaya, Shahabad, Monghyr, Bhagalpur and Santhal Parganas districts of Bihar and also from parts of Burdwan in Bengal. During the succeeding week, flights visited Saran, Champaran and Muzaffarpur districts causing damage to maize, cotton and ahar. According to Fletcher [1931] swarms occurred as far east as Assam. There are no further reports for 1907.

A study of the Indian Daily Weather records for this period shows that there was along break in the monsoon from the 6th to the 20th July on the Gangetic plains. In consequence of an abnormal pressure distribution, in which the low pressure trough had moved north close to the hills, strong dry westerly winds were prevalent in the region of the United Provinces and Bihar during this period, which synchronises with the appearance of swarms in the eastern parts of the United Provinces and the adjoining parts of Bihar. After the 20th, easterly winds and good rainfall are recorded in these areas, and it is to be presumed that locusts were swept out of these areas during the latter half of July and during August.

Central Provinces and Berar.—Data from the season and crop reports of the *Gazette of India* show that locust swarms were active in various parts of the Central Provinces: Damoh, Saugor, Mandla, Betul, Chindwara, Nagpur, Wardha, Buldana, Yeotmal and Akola. In 1907, however, the *Bombay locust* swarms were prevalent, and extended in June-July into Berar (Akola, Buldana and Yeotmal etc.,) and Betul, Nimar, Chindwara, Wardha and Nagpur in Central Provinces. The swarms of the *desert locust* were apparently confined to the northern parts: Damoh, Saugor and Mandla districts and passed over the States of Raigarh and Sakti by the end of June. Strong westerly winds were prevalent in most parts of the Central Provinces during June and July and had presumably functioned in directing the movements of *Schistocerca* eastwards into Bihar and of *Patanga* from the northern districts of Bombay into Berar and Central Provinces.

Summer Breeding: *Rajputana.*—There was fairly good rainfall in July followed by heavier rainfall in August. The only recorded cases of breeding were in Bap and Mayajlar in Jaisalmer and on both sides of the Bikaner and Marwar borders (in parts of Didwana and Nagaur in Marwar and in parts of Sujangarh in Bikaner). There is little doubt, however, that oviposition had occurred in many other parts of the Rajputana area. According to the Jodhpur State Administration Report for the year ending 30th September 1907: "Flights of locusts passed over the country in the months of July and August laying eggs in certain Parganas. For their destruction, although a regular and timely campaign was started, yet so eminent a success could not have been attained, had not nature helped in clearing the country of this scourge; the rains were continuous and heavy enough to destroy the vitality of the eggs and no larvae came out." There is thus fairly clear evidence of the adverse effect of heavy and continuous rainfall on breeding even in easily drained sandy areas.

Sind.—There are no records of breeding in the desert areas of Sind, but it is possible that as in Rajputana some breeding had actually occurred in Mithi, Chachro and Nagar areas.

Punjab.—There were numerous flights in many districts of the Punjab during June, July and August. During August, swarms from the United Provinces would appear to have been carried into the Punjab and a flight reached Simla at this time. Hoppers were reported, however, only from Rohtak and Gurgaon in the east and from Gujrat and Gujranwala in the north.

On the whole. summer breeding was poor and as the monsoon practically withdrew from North-West India about the end of August, there was no late breeding anywhere.

IV.—*Autumn* 1907.—(September—November 1907).

Autumn Flights: *Baluchistan.*—Several flights were reported in Loralai, Sibi and Kachhi areas during September, October, November and December and damage to young rabi and jowar crops was said to have been done in Kachhi and Loralai. Swarms visited Sheh Lakhra in Lasbela in the first week of September and damaged crops. In Mekran, locusts were reported to have visited Dasht and damaged cotton in the third week of December. In Jhalawan, rabi crops were damaged in the Mula Pass during the last week of December.

Sind.—There were numerous flights in most parts of Sind during the autumn months. There is only one record for December in Karachi

district, where green-gram crops were damaged by locusts in Shahbunder and Sujawal during the second week of December.

Punjab.—There are no records of flights during autumn except for a swarms observed in Multan and Dera Ghazi Khan in October.

Central India.—There is one record of damage by locusts during week ending 16th November in pargana Kolaras of Gwalior.

Western India States.—Locusts appeared in Radhanpur during the latter part of November and early in December, and in Cutch (Mandvi) during the first week of December.

Central Provinces.—There are records of locust flights in Nimar, Chindwara, Betul, Nagpur, Wardha, Akola and Buldana in October and November, but these were evidently concerned with swarms of the Bombay Locust, which were gradually moving westwards to the Western Ghats at this period.

Summary of Events in 1907.

(1) There was fairly satisfactory winter and spring rainfall in south Iran and Oman, and in Upper Baluchistan and the Punjab; spring rainfall was fairly high especially in February.

(2) Over-wintering was noticed in Sind and many districts of Punjab. In January-February, swarms gradually drifted into the valleys from the plains. Swarms also entered Mekran, Kharan and Chagai in spring from south Persia.

(3) Spring breeding occurred in parts of Loralai district in April-May, and is presumed to have occurred in Kharan and Chagai also at this time. In the Punjab, breeding took place in 6 districts in the north.

(4) Punjab-bred swarms flighted into the United Provinces and Central India in May-June and reached Bihar and parts of Bengal (possibly even Assam) during a break in the monsoon in the early half of July.

(5) Western flights began to appear in Sind towards the end of June and spread into Rajputana, Punjab and United Provinces in July.

(6) There was fairly good and even heavy rainfall in the latter half of July and during August. Breeding occurred only in 4 districts of the Punjab and in parts of western Rajputana. It was said that as a result of heavy rainfall, eggs laid in the soil were mostly destroyed by excessive soil moisture.

(7) As there was no rainfall after August, there was no late breeding. The autumn flights were comparatively limited in number. Several swarms were reported from Sind and Baluchistan during the autumn months, but very few from the Punjab. There were very few flights directed eastwards—the only report recorded being from Gwalior in Central India in November.

(8) Some swarms reached Radhanpur and Cutch during November and December.

SECTION X

LOCUST DATA PRIOR TO 1888

IT is only since 1872 that a system of publishing weekly or fortnightly Season and Crop Reports would appear to have been regularly followed in the official Gazettes of the various provinces of India. Prior to 1872, Season Reports of a sort would appear to have been issued in some provinces, in respect of crops like cotton. As far as available, information on locusts was extracted, and in the case of the years 1863 and 1869, when a severe locust infestation was associated with famine or drought, fairly voluminous reports had been published in the *Gazette of India*, as also in the proceedings of the Punjab Government in respect of locust destruction measures then undertaken. E. S. Cotes has recorded much of this information in his report "The Locust of North West India" [1891].

Since 1873, however, fairly detailed information on locusts is on record in the weekly crop reports, studies of which have thrown much light on the locust developments of this period, and especially on those of the year 1878.

CHAPTER I

PERIOD: 1861—1868

YEAR 1861

A. WEATHER NOTES 1861

Monsoon Rainfall 1861 (*in inches*)

1861	May	June	July	August	September
Karachi	..	..	1·12	3·34	..
Rohri	1·79	..	0·15	1·85	..
Bhuj	?	?	4·19	3·04	1·10
Hissar	1·80	2·30	3·50	6·40	2·60

The monsoon was probably somewhat defective in the desert areas, though the rainfall in August was fairly satisfactory.

B. LOCUST DATA 1861

The only item of information for this year is the following statement made in the *Gazetteer of Sind* [Aitken, 1907]: 'There was distress on account of the destruction of both harvest and pasture by locusts in 1860-61 and 1877-78'. Apparently the official year at that time commenced from November and ended in October. The year 1860 was a year of defective monsoon in general, as a result of which a famine prevailed in East Rajputana and the United Provinces. The rains of 1861 were presumably more conducive to the cultivation of crops and the growth of grass in the desert, which, however, would seem to have been destroyed by locusts.

YEAR 1862

A. WEATHER NOTES 1862

Monsoon Rainfall 1862 (*in inches*)

1862	May	June	July	August	September	October
Karachi	..	0·06	2·82	0·75	0·39	0·26
Rohri	0·35	..	0·78	..	0·58	..
Bhuj	?	1·05	7·76	6·77	5·27	14·89
Multan	0·01	0·27	1·46	0·34	2·34	2·48
Hissar	0·60	4·90	7·60	3·70	..	2·00

Col. Brooke in his report on 'The Famine of 1869 in Rajputana' (*Gazette of India*, 1870), says; 'After the famine of 1860-61, the rainfall in 1862, and again in 1863, was excessive in Rajputana. At Ajmer it was 43·40″ and 43·90″ respectively.....". From the rainfall data tabulated above, it is seen that in Sind and south-west Punjab, rainfall was comparatively scanty, though fairly high in Eastern Punjab and in Cutch. In October good rainfall apparently occurred.

B. Locust Data 1862

I & II. *Winter and Spring* 1862.—No data.

III. *Summer* 1862.—*Breeding*. In the wake of good rainfall, extensive breeding apparently took place in the Sind-Rajputana desert.

Towards the close of August and the beginning of September locusts were said to have been doing much damage to crops in the Mirpur, Rohri, Shikarpur, Nasirabad and Mehar talukas. Apparently the swarms came from the direction of Jaisalmer where they were reported to have destroyed the crops.

IV. *Autumn* 1862.—(September to November 1862).

Punjab. Swarms hailing from the deserts of Rajputana, Bahawalpur and Sind appeared in October 1862 in the Derajat (Dera Ismail Khan and Dera Ghazi Khan districts) and the Multan division.

Sind. Locusts again visited the Nara division (the non-desert talukas) of Thar-Parkar district in great numbers in the last week of December and caused great damage to Rabi crops.

Cutch. According to the *Gazeteer of Bombay Presidency* (Vol. V-1880), 'The rainfall in 1862 was heavy—34 inches. The rains closed in October with a tremendous rain-storm, which caused heavy damage to crops and life. This loss was increased by a plague of locusts, which apparently came from the east and north. After devastating Cutch, they would seem to have been drivèn west and out to sea. Ship Captains from Muscat and Zanzibar, some hundred miles from Mandvi, found the sea covered with their dead bodies.'

Bihar. It is stated in W. H. Grimley's Report to the Bengal Government (dated 11th July, 1883) that locusts visited Monghyr in 1862 (presumably in the autumn).

Summary of events in 1862.

(1) There was apparently widespread breeding in the desert areas in July to September and the new generation began to migrate in September.

(2) Autumn flights occurred in Sind and the Punjab in the west, in Cutch area in the south and reached Monghyr in Bihar towards the east.

YEAR 1863

A. Weather Notes 1863

I.—*Winter-Spring Rainfall* 1862-1863 (*in inches*)

1862-1863	November	December	January	February	March	April
Karachi	0·05	..	1·00	0·11	..	..
Jacobabad	0·74	..	0·15	..	..	..
Nagar-Parkar	??	??	1·68	..	..	..
Multan	0·27	..	0·51	0·02	0·34	0·45
D. I. Khan	??	??	1·00	..	..	..
Hissar	0·50	0·10	1·70	..	0·40	..

Winter rainfall was apparently fairly satisfactory, especially in January.

II.—Monsoon Rainfall 1863 (*in inches*).

1863	May	June	July	August	September	October
Karachi	..	1·27	5·28	4·15	..	..
Jacobabad	..	0·70	2·46	0·44	..	..
Umarkot	..	9·12	1·15	1·62	1.18	4·37
Nagar-Parkar	..	10·24	2.66	4·63	0·85	4·34
Bhuj	..	16·40	3·37	0·98	2·40	0·70
Multan	..	0·80	3·20	5·60	..	..
D. I. Khan	..	0·80	3·20	5·60	..	..
Hissar	1·00	3·60	11·30	7·60	..	0·70

The monsoon began in June with heavy rainfall. Precipitation in July and August was fair. There were heavy falls in Thar in October.

B. Locust Data 1863.

I. *Winter* 1862-63. (December 1862 to February 1863).

According to Cotes [1891], large flights appeared in February and March in Shahpur and Hissar areas in the Punjab.

II. *Spring* 1863. (March to May 1863).

Eggs were laid in February and March in north Punjab.

III. *Summer* 1863. (June to August 1863).

Summer flights. A large flight appeared in July 1863 at Muzaffargarh from Rajputana, and swarms appeared in Hissar in June and July. According to the Report of the Financial Commissioner in Punjab, dated June 25, 1863, 'the young brood took wing in the latter part of May in the Punjab. Large swarms were making their appearance in June, from Murree and Hazara in the north to Hissar and Rohtak in the south, from the Sulaiman Range in the west to the Himalayan Range in the east. It appears from the newspapers that they have passed over the North West Provinces (United Provinces) and are spreading towards the south, to the plains of Berar and Guzarat'. A large flight was reported by John Strip to have been seen at Karachi in the summer (probably June-July) of 1863.

Summer breeding. Punjab. Egg laying was reported in June-July from Lahore, Gurdaspur, Sirsa, Hissar, Rohtak, Patiala and other parts south of the Sutlej. Oviposition also took place in Rawalpindi, the Salt Range and other parts of North Punjab, and in the Derajat and Peshawar divisions. Hoppers were found in vast numbers towards the end of July in Lahore and Gurdaspur.

Rajputana. Locusts were reported to be laying eggs broadcast in Bikaner and other parts of Rajputana in July.

IV. *Autumn* 1863. (September to November 1863).

According to Cotes [1891], ' considerable flight reached Dacca in the cold weather'.

Summary of events in 1863.

(1) Overwintered swarms were present in the Punjab in January and February.

(2) Egg laying occurred in parts of north Punjab in February-March and hoppers became adult by May.

(3) Punjab-bred flyers as well as swarms from beyond the Sulaiman Range flew east into the United Provinces and south-east into Central Provinces in June.

(4) Breeding occurred all over the Punjab from the North West Frontier up to Hissar and Rohtak during July-August, and also over the Sind-Rajputana area.

(5) Autumn flights presumably took place, of which one reached as far east as Dacca in November-December.

YEAR 1864

A. Weather Notes 1864

Monosoon Rainfall 1864 (*in inches*).

1864	May	June	July	August	September
Karachi	0·29	..	3·12	1·74	..
Unarkot	..	..	2·83	1·78	..
Bhuj	..	0·01	5·69	1·58	..
Multan	1·60	0·48	0·73	1·69	..
Hissar	1·80	0·40	1·00	4·50	1·70

The monsoon of 1864 was apparently defective. According to Col Brooke [1870], 'the rains broke up early in 1864, and the *khureef* at Ajmer was only half an average crop'.

B. Locust Data 1864.

I.—*Winter-Spring* 1864. No data.

II. *Summer* 1864. (June to August 1864).

Accodding to Cotes [1891], a large flight passed through the Hissar Sirsa and Gurgaon districts in July, and laid eggs which hatched in the middle of August.

III. ***Autumn*** 1864. No data.

YEAR 1865

A. Weather Notes 1865

I.—*Winter-Spring Rainfall* 1864-1865 (*in inches*)

1864-1865	November	December	January	February	March	April
Kaaachi	..	0·35	3·38	0·44	0·46	..
Multan	..	0·18	0·75	2·32	0·86	0·16
D. I. Khan	..	1	0·80	2·20	0·60	1·10
Hissar	..	..	0·90	2·00	0·70	0·50

II.—*Monsoon Rainfall* 1865 (*in inches*)

1865	May	June	July	August	September
Karachi	..	..	0·22	1·61	..
Umarkot	..	..	..	20·08	0·45
Nagar-Parkar	..	0·04	2·59	8·17	0·03
Bhuj	..	0·05	2·83	7·73	0·99
Multan	..	..	0·20	0·64	0·15
D. I. Khan	..	..	0·20	0·70	0·60
Hissar	0·30	1·50	3·50	10·10	7·30

Spring rainfall would appear to have been fairly good. The monsoon was late in arriving and there was good rainfall in the desert and east Punjab in August.

According to Col. Brooke [1870], 'In 1865, the rains commenced very late (on 5th August), so that all the early crops were lost, and only half the later crops were saved in Rajputana'.

B. Locust Data 1865.

I. *Winter-Spring* 1865. (December 1864 to May 1865). No data. Spring rainfall was, however, copious and breeding in the west on a large scale should be considered probable.

II. *Summer* 1865. (June to August 1865).

Summer flights—Punjab. According to Cotes [1891], flights appeared in Hissar in June and laid eggs which hatched by the end of the month. Further flights were seen in July and August.

Bihar. According to the Report of the Commissioner of Bhagalpur and Sonthal Parganas [1890] [Cotes, 1891], a flight of locusts passed through Durbhunga (possibly in June). Locusts were also reported to have passed over Manbhoom without doing any serious damage to the harvest (November?) (Hunter's Gazetteer).

III. *Autumn* 1865. (September to November 1865).

According to Cotes [1891], flights appeared in Hissar also in November.

Summary of events in 1865.

(1) There was presumably good spring breeding in Baluchistan and in Iran and Oman territory.

(2) Western flights passed through Rajputana and Hissar eastwards in June as far as Durbhunga in Bihar.

(3) Summer breeding occurred in Hissar and probably also in parts of Rajputana.

(4) Autumn flights occurred in Punjab and probably also in Sind.

YEAR 1866

A. Weather Notes 1866

I.—*Winter-Spring Rainfall* 1865-66 (*in inches*).

1865-1866	November	December	January	February	March	April
Karachi	..	0·84	0·75	0·18	0·21	..
Jacobabad	..	1·10	0·53	..	0·25	..
Multan	..	0·56	..	0·20	0·10	..
Hissar	..	2·40	2·70	0·50	..	0·30

II.—Monsoon Rainfall 1866 (*in inches*).

1866	May	June	July	August	September
Karachi	..	..	..	11·61	0·76
Umarkot	..	1·12	0·18	11·69	..
Nagar-Parkar	..	3·11	1·87	14·76	0·33
Bhuj	..	0·52	4·55	14·39	1·26
Multan	0·70	..	0·30	1·16	..
Hissar	..	1·10	5·20	3·80	0·10

Monsoon was defective in July, in the desert, but there was very heavy rainfall in August.

B. Locust Data—1866

I & II. *Winter and Spring* 1866. No data; as the winter rainfall was fairly good, spring breeding might have occurred in the western areas.

III. *Summer* 1866. Summer flights appeared in *Hissar* in June and eggs were laid in July, and hoppers appeared in August. Eggs were laid in *Bikaner* in July.

IV. *Autumn* 1866. No data.

YEAR 1867

A. Weather Data 1867

Monsoon Rainfall 1867 (*in inches*).

1867	May	June	July	August	September
Karachi	..	..	0·02	1·57	0·73
Umarkot	0·82	..	..	8·87	0.60
Mithi	..	0·08	1·12	3·60	..
Nagar-Parkar	..	0·18	0·56	3·50	3·75
Bhuj	..	..	0·60	2·42	4·94
Multan	0·80	..	2·10	0·50	0·60
Hissar	0·50	0·90	10·30	7·40	0·40

The monsoon began late in the desert. Light rain in July, fair amount in August, light in September. Heavier monsoon in south Punjab.

(Winter rainfall light in Sind and Rajputana).

B. Locust Data 1867

Summer 1867. The only information for 1867 is that recorded by Cotes [1891] to the effect that a small flight appeared in Hissar district in July 1867. It is likely that similar flights had appeared in the Rajputana areas also about this time; light breeding in August and September should have been possible.

YEAR 1868

A. Weather Notes 1868

Monsoon Rainfall 1868 (*in inches*).

1868	May	June	July	August	September
Karachi	..	0·19	1·24	0·79	0·02
Umarkot	..	0·10	1·15	4·69	1·04
Mirthi	..	0·08	1·12	2·50	..
Erinpura	0·04	0·22	2·98	1·96	0·10
Bhuj	..	2·92	0·97	4·46	0·16
Multan	0·10	..	0·10	..	..
Hissar	..	1·60	3·20	..	..

According to Col. Brooke, 'there was little rain in Ajmer and Jaipur in June, a fair amount in July, and little in August and September. At Jodhpur, there was no rain whatever during the season. The rainfall was scanty not only in Rajputana, but also in the neighbouring countries, and great scarcity overshadowed the North West Provinces of Hindusthan'.

In the Thar area, however, there was a fair amount of rain in August. In south Punjab, there was a failure of rain in August and September.

B. Locust Data 1868.

No records available.

CHAPTER II

PERIOD: 1869-1875

YEAR 1869

A. WEATHER NOTES 1869

I.—*Winter-Spring Rainfall* 1868-1869 (*in inches*).

1868-1869	November	December	January	February	March	April
Karachi	0·45	0·84	2·44	1·12	1·69	..
Jacobabad	..	0·19	0·96	0·50	2·59	0·44
Multan	..	0·20	1·10	0·10	4·00	0·80
D.I. Khan	..	1·20	0·10	..	3·30	0·70
D.G. Khan	..	0·70	1·60	0·10	2·40	..
Hissar	..	..	1·10	0·60	1·80	..

There was good winter and spring rainfall in Sind and Punjab, and presumably also in Baluchistan and Persia, conducive to the production of spring breeding.

II.—*Monsoon Rainfall* 1869 (*in inches*).

1869	May	June	July	August	September
Karachi	..	0·19	12·97	1·33	8·28
Jacobabad	..	0·42	3·09	2·10	1·70
Umarkot	..	2·35	16·35	1·58	1·45
Mithi	..	1·20	8·65	4·14	4·42
Nagar-Parkar	0·77	1·39	13·45	2·25	9·27
Erinpura	..	..	7·60	2·18	2·54
Bhuj	..	1·11	9·35	5·53	6·01
Multan	..	0·60	2·70	2·80	1·90
D.G.Khan	..	0·90	4·10	1·90	1·10
Hissar	0·20	..	2·50	1·80	5·10
D.I.Khan	..	2·00	1·10	1·30	2·40

Monsoon began in June with light falls: there was very heavy rain in July in the southern areas of Sind and Rajputana, though little in the Punjab; in August there was comparatively little rain: in September, there was fairly heavy rain in the southern parts and in Hissar.

B. LOCUST DATA 1869

I. *Winter* 1869. No data available.

II. *Spring* 1869. (March to May 1869).

Punjab. Swarms from the west from beyond the Sulaiman Range appeared in April in the Dera Ismail Khan district in the North West.

During May, numerous swarms of locusts were recorded in various district of the Punjab, generally coming from the west and passing on, either east, north-east or north—Dera Ismail Khan, Kohat, Bannu and Hazara; Shahpur, Gujarat, Sialkot, Gurdaspur and Amritsar; Dera Ghazi Khan, Multan and Gurdaspur.

Rajputana. According to Col. Brooke [1871], 'flights entered Marwar from Jaisalmer at the end of May and laid eggs in every direction. These hatched as the rains set in and by the end of August, the young locusts had spread over the whole famine tract laying fresh eggs wherever there was sand.' Apparently the above statements are only partly correct, for as there was no rain in Marwar area till July, eggs could not have been laid at the end of May. Presumably, flights merely passed over the country and egg laying occurred during July only after the fall of heavy rains.

III. *Summer* 1869. (June to August 1869)

Summer flights and breeding. The movements of swarms from the west, which began early in May in the Punjab, would appear to have passed over Rajputana into the *United Provinces* as far as Hamirpur (and presumably also further east) during June. In July, flights were found in many districts, and their general movement was from east to west in view of the prevalent easterly winds.

In the *Punjab*, swarms passed over Dera Ghazi Khan and Multan in June. In July some flights reached Simla and others were reported over Hissar, Gurgaon, Karnal, Ambala, Amritsar and Sialkot, the direction being, in many cases, east to west. According to Cotes [1891], egg laying occurred in Hissar in July and also in the latter part of September and the beginning of October.

In *Western India States,* flights reached as far as Deesa (Palanpur) by June and eggs were laid in July.

In *Rajputana,* egg laying occurred in extensive areas, in July and August after rainfall and 'the hoppers were found moving in dense masses over the area destroying every green plant in their way. Crops were eaten down to the ground. The loss to the country by locusts was about 75 per cent of the crop'. Damage by locusts was observed not only in Marwar, but also in Bikaner, Jaisalmer, Ajmer, Kishengarh, west Jaipur, Tonk and the northern part of Mewar. In Tonk, locusts laid eggs in sand heaps and river beds, and bands of hoppers, which emerged in myriads, destroyed the crops and invaded the houses in the town.

IV. *Autumn* 1869. (September to November 1869)

Late summer breeding.

Punjab. During the first week of September numerous swarms of locusts were reported by the Deputy Commissioner, Hissar, to be coming into Hissar and Gurgaon from Bikaner side and to be laying eggs. According to Cotes [1891], eggs were laid in the latter part of September and the beginning of October in Hissar.

Sind. According to Major Tyrwhitt, Political Superintendent of Thar-Parkar, 'in consequence of good and seasonable rainfall in July, cultivation was much extended. But on the 15th September, 1869 locusts appeared. From that date up to the end of February 1870, they never left the country. They bred there and the country was for miles and miles carpeted with these pests.' There was heavy damage to crops (*bajri, til* and cotton) all over the area. The swarms that invaded Thar-Parkar area had evidently come from Rajputana and it is likely that similar late breeding had occurred in the adjoining Mallani area also.

Autumn flights. Swarms of the new generation produced in Rajputana began to fly about in the desert and destroy the autumn crops. In October to November, in *North Gujarat*, the area north of the Mahi River—between Viramgam, Wadhwan and Dholera including Ahmedabad—suffered from serious visitations of locusts. South of the Mahi, they appeared also in *Broach* district. In *Kathiawar*, huge flights of locusts devoured the rabi crops. 'Their numbers darkened the sun and large branches on which they settled were broken by their weight. They ate not only the leaves but also the bark of trees.' In *Cutch*, locusts appeared all over the State and utterly ruined the millet crops in places. According to the Bombay *Gazetteer—Khandesh*, 'a large swarm of locusts crossed the Khandesh district north to south.' (1880-XII). Presumably, the swarm had come from Barwani area in Central India.

There were also flights in the States of east Rajputana during autumn, but there is no indication as to whether their movements extended further east into Central Provinces or United Provinces.

Summary of events in 1869.

(1) Flights from the west appeared in western Punjab in April and laid eggs in Dera Ismail Khan, Dera Ghazi Khan and Amritsar districts and hoppers were seen in May.

(2) Western flights commenced in May and passed over the Punjab and Rajputana into the United Provinces.

(3) With the fall of rain in July, widespread oviposition occurred in Hissar in Punjab and in various parts Rajputana, specially Marwar, Ajmer, Bikaner and Tonk; and hoppers were found in August-September.

(4) There being good rainfall also in September, late breeding occurred in parts of south Punjab and in Thar-Parkar area and probably also in Mallani.

(5) Autumn flights were found in Sind, Cutch, Kathiawar, north Gujarat, Broach and Khandesh and also in east Rajputana.

YEAR 1870

A. Weather Notes 1870

I.—*Winter-Spring Rainfall*—1869-1870 (*in inches*)

1869-1870	November	December	January	February	March	April
Karachi . . .	..	..	..	..	0·07	..
Shikarpur . . .	..	..	..	..	1·12	..
Rohri . . .	..	..	..	..	2·28	..
Jacobabad . . .	..	..	..	..	0·72	..
Multan . . .	..	..	..	..	0·80	..
D.I. Khan . . .	..	..	..	0·10	0·40	..
Hissar . . .	..	..	..	..	1·10	0·10

But for March, the winter-spring period would appear to have been dry in the Indian areas. Possibly the rainfall was defective in the Persian Baluchistan areas also.'

II.—*Monsoon Rainfall*—1870 (*in inches*)

1870	May	June	July	August	September
Karachi	..	2·21	0·09	2·20	..
Umarkot	..	..	5·11	0·53	..
Mithi	..	3·44	0·82	0·32	..
Nagar-Parkar	..	6·12	5·10	1·03	..
Bhuj	..	1·68	5·91	0·21	1·68
Erinpura	0·42	1·18	4·22	0·78	1·82
Multan	..	0·20	..	1·00	..
Hissar	0·20	6·90	3·40	6·90	0·80

The monsoon began early and also ended early. Rainfall was comparatively high in June and below average in August.

B. Locust Data.—1870

I. *Winter*, 1869-1870. Overwintering locusts were present in Thar-Parkar district and probably other parts of Sind as also in parts of the Punjab.

II. *Spring*, 1870. According to Cotes [1891], eggs laid by the cold-weather flights of 1869 hatched in March 1870 in the Jhelum district, and the young hoppers did some damage to the rabi crops and were destroyed by trenching.

Locusts were reported to have been present in Yusufzai area of Peshwar district in April.

III. *Summer*, 1870. According to Cotes [1891], locusts appeared in Hissar and Amritsar early in July and at Simla by the end of the month. In August, flights appeared in Multan, Karnal, Patiala, Hissar and Ludhiana. In Amritsar, according to the district report locusts did a little damage to the crops, and young wingless locusts appeared at the end of August and early part of September but were all destroyed [Cotes 1891].

IV. *Autumn*, 1870. Some damage was caused to crops by locusts in Ahmedabad (Statistical Atlas of the Bombay Presidency, 1925).

Summary of events in 1870

(1) Some overwintering in Sind and Punjab.

(2) Light breeding in Jhelum district in March to April.

(3) Light breeding in Amritsar in August.

(4) Flights in Ahmedabad in autumn.

YEAR 1871

A. Weather Notes 1871

I.—*Winter-Spring Rainfall*—1870-71

Rainfall defective in Indian areas

II.—*Monsoon Rainfall*—1871 (*in inches*)

1871	May	June	July	August	September
Karachi	..	..	0·06	..	..
Umarkot	..	..	1·70	0·40	..
Mithi	2·15	..	0·55	3·69	..
Erinpura	0·02	0·64	4·62	1·52	0·16
Hissar	0·20	4·50	1·70	..	0·70

Monsoon—a fairly average one. Rainfall defective in Sind.

B. LOCUST DATA 1871

I. *Winter-Spring* 1871.—No data.

II. *Summer Autumn* 1871.

Ajmer. Locusts alighted on crops in Beawar Pargana and destroyed them, possibly in September or October.

Presumably breeding had occurred in July-August in parts of the desert and the resulting swarms had probably attacked the crops in Ajmer.

YEAR 1872

A. WEATHER NOTES 1872

I—Winter-Spring Rainfall—1871-1872 (*in inches*)

1871-1872	November	December	January	February	March	April
Karachi	0·04	0·02	0·09	..	..	..
Jacobabad	..	0·08	0·18	0·02	0·55	0·57
Multan	..	0·40	0·10	..	..	0·20
D.G.Khan	..	..	..	..	2·30	..
D.I.Khan	..	..	..	0·50	1·20	0·30
Hissar	..	1·20	1·60	0·10	0·80	0·30

Good spring rainfall in March.

II—Monsoon Rainfall—1872 (*in inches*).

1872	May	June	July	August	September
Karachi	..	0·06	6·32	0·02	0·99
Nagar-Parkar	..	2·17	8·71	0·97	1·53
Bhuj	..	4·79	8·68	2·15	1·44
Erinpura	0·50	2·04	1·54	10·00	1·25
Hissar	0·90	3·00	10·00	10·20	2·70
Multan	..	..	3·00	1·50	0·70
D.I.Khan	1·60	..	3·00	0·30	1·00

Apparently a good monsoon in N. W. India.

B. LOCUST DATA 1872

I. *Winter* 1871-1872. *No data available.*

II. *Spring* 1872. There are no data in regard to India proper. The following statement was made by Col. Miles—who was Political Resident, Mewar in 1891: 'In 1872, the district of Mekran in Baluchistan was devastated by locusts swarming in small detachments all over the country'. Presumably there was extensive spring breeding in Mekran after favourable rainfall, as was observed in 1928 and 1930, during the last great cycle. Major Euan Smith C.S.I. mentions as follows, in his report on the Perso-Afghan Frontier Commission of 1871-1872, 'At Ahuwan on the 25th May 1872, we were surprised to find the country between this place and Guchah swarming with an insect unknown to us previously, with the body of a large beetle and the legs of a grasshopper. The natives called

it a 'Locust' but it certainly was not the locust of Egypt and Syria' [Smith, 1873],—evidently the insects noticed were the 4th and 5th stage hoppers of the Desert Locust moving in bands, indicating spring breeding in the northern parts of Persia. Presumably there should have been an extensive spring invasion by yellow locust swarms in Persia in 1872.

The first indication of summer migration from the west was a flight recorded by Surgeon-Major Moore to have passed over Sirohi on the 31st May 1872 [Cotes 1891]. This would show that flights had started entering Sind and Punjab from Baluchistan by the middle of May.

III. *Summer* 1872. (June to August, 1872)

(*a*) *Summer flight—Sind.* The earliest record of swarms in Sind was of small flights of locusts crossing the Nawabshah area of Hyderabad district west to east during the latter half of June, and at about this time there were also reports from Shikarpur district. During July and August, there were numerous reports from all parts of Sind.

Rajputana. During the first part of June there were flights of locusts in various parts of Jaisalmer, and during the latter half, a flight was recorded near Alwar. During July, swarms were reported from Marwar, Haraoti and Tonk and other parts of Rajputana.

Western India States. On the 4th July, a flight of locusts was observed at Ahmedabad in Gujarat passing in a south-west to north-east direction.

Punjab. The earliest record of flights in the Punjab was that of a swarm in the Amritsar tahsil on the 4th July. On 5th and 6th July, there were reports from Ludhiana, Hoshiarpur, Jullundur and Shahpur districts. In the latter part of the month, locusts appeared also in Karnal, Dera Ghazi Khan and Hissar.

(*b*) *Summer breeding—Rajputana.* There was good rainfall in July and August and oviposition would appear to have occurred in Marwar, Bikaner, Jaisalmer and Alwar possibly also in Ajmer. Hoppers appeared at the beginning of August and were being found till the end of September. In Marwar, breeding was apparently specially heavy in Nagaur, Jalor and Barmer areas and control measures were said to have been adopted.

Sind. There are no records in regard to breeding in Sind, but as rainfall was favourable in July and as breeding is known to have taken place in 'parganas of Marwar adjoining Sind, including Barmer,' its occurrence in the desert areas of Thar-Parkar appears quite likely.

Punjab. Following good rainfall in July and August, extensive egg laying took place in the Punjab from July onwards and hoppers were found almost every where in August and September, in Bannu, Jhelum and Gujranwala in the north; in Ludhiana, Amritsar and Hoshiarpur in Central Punjab; in Multan in the south-west; and in Hissar, Rohtak and Ferozepur in the south-east.

IV. *Autumn* 1872. (September-November 1872)

Breeding.—Hoppers were found in considerable numbers in Rajputana and the Punjab till the end of September, and even in the early part of October, in north Marwar.

Autumn flights—Sind. Swarms were reported from many parts of Sind between September and December, generally flying east to west and often causing damage to crops.

Punjab. There were several flights during autumn in Jullundur, Ludhiana, Dera Ismail khan and Gurdaspur. In November and December, there were only two reports, one from Hazara on 4th and 6th November, and the other in the second week of December from Shahpur.

Rajputana. There were flights in Marwar, Sirohi, Ajmer-Marwara, Bikaner and Mewar. In Jodhpur State, according to the *Rajputana Gazetteer*: III-A, 'a flight four miles in length and 100 feet in depth is said to have been seen in the autumn, taking four hours to cross the road.'

United Provinces. Locusts were reported at Agra and Fatehgarh early in October, and from various districts as far east as Cawnpore early in November.

Central India. A flight passed over Ratlam on the 2nd November.

Western India States. Locusts passed over Viramgam into Kathiawar about the middle of September, at which time damage to crops was also reported in Kaira district and Wadhwan State.

Summary of events in 1872.

(1) Winter-spring rainfall was presumably favourable for spring breeding in Mekran. Presence of hopper bands was recorded in May in the Semnan area in Persia, where widespread breeding had probably occurred.

(2) Summer flights commenced at the end of May and were reported from Sind and Rajputana in June and early in July in Western India States and Punjab.

(3) As a result of good rainfall in July, breeding occurred in many parts of western Rajputana and Punjab in August—September.

(4) Autumn flights occurred in Sind and Punjab (mostly westwards) and in east Rajputana, United Provinces and Central India (generally eastwards). The eastern-most limit would appear to have been Cawnpore in November. Some flights passed south into north Gujarat and Kathiawar in September.

YEAR 1873

A. Weather Notes 1873

I.—*Winter-Spring Rainfall* 1872-1873 (*in inches*)

1872-73	November	December	January	February	March	April
Karachi . . .	..	..	1·36	..	0·01	..
Jacobabad . .	..	..	1·09	..	..	..
Multan . .	..	..	0·50	..	..	..
D.I.Khan . .	..	..	0·10	..	0·80	..
Hissar . . .	..	1·20	..	..	0·20	..

Except for January and March, there was no rainfall in the Indian areas.

II.—*Monsoon Rainfall* 1873 (*in inches*)

1873	May	June	July	August	September
Karachi	0·03	..	..	0·63	..
Jacobabad	0·58	..	0·03	2·47	..
Nagar-Parkar	..	..	2·56	8·10	..
Bhuj	..	..	2·52	2·58	0·01
Erinpura	0·80	1·80	3·80	4·90	1·60
Multan	1·90	..	1·90	2·20	..
D. I. Khan	1·90	..	2·60	2·90	0·10
Hissar	1·20	0·40	4·10	3·20	1·20

A fair amount of rain in July and August: defective on the whole.

B. Locust Data 1973

I. *Winter* 1872—1873.

Punjab. A flight of locusts visited Gujranwala on the 27 January and another the Jhelum district about this time.

No records of locusts from other provinces.

II. *Spring* 1873. (March to may 1873).

Punjab. Locusts appeared in large flights in Rawalpindi and Kohat during March. On 2nd April, a large flight was found passing over Isakhel tahsil—east to west—in Dera Ismail Khan. In Jhelum district *hoppers* hatched out at the end of March in Chakwal tahsil and measures were taken to have them destroyed. *Breeding* also occurred in Kohat, where hoppers appeared in most parts of the area at the end of April.

On the 16th May, a flight of locusts passed over Ahmadzai in Bannu from west to east. In the course of the week following, several flights were reported from Gujranwala, Ludhiana, Amritsar and Jullundur, passing in a west to east direction in general. Evidently these movements represent the usual summer migration from the west into India.

III. *Summer.* 1873. (June to August 1873).

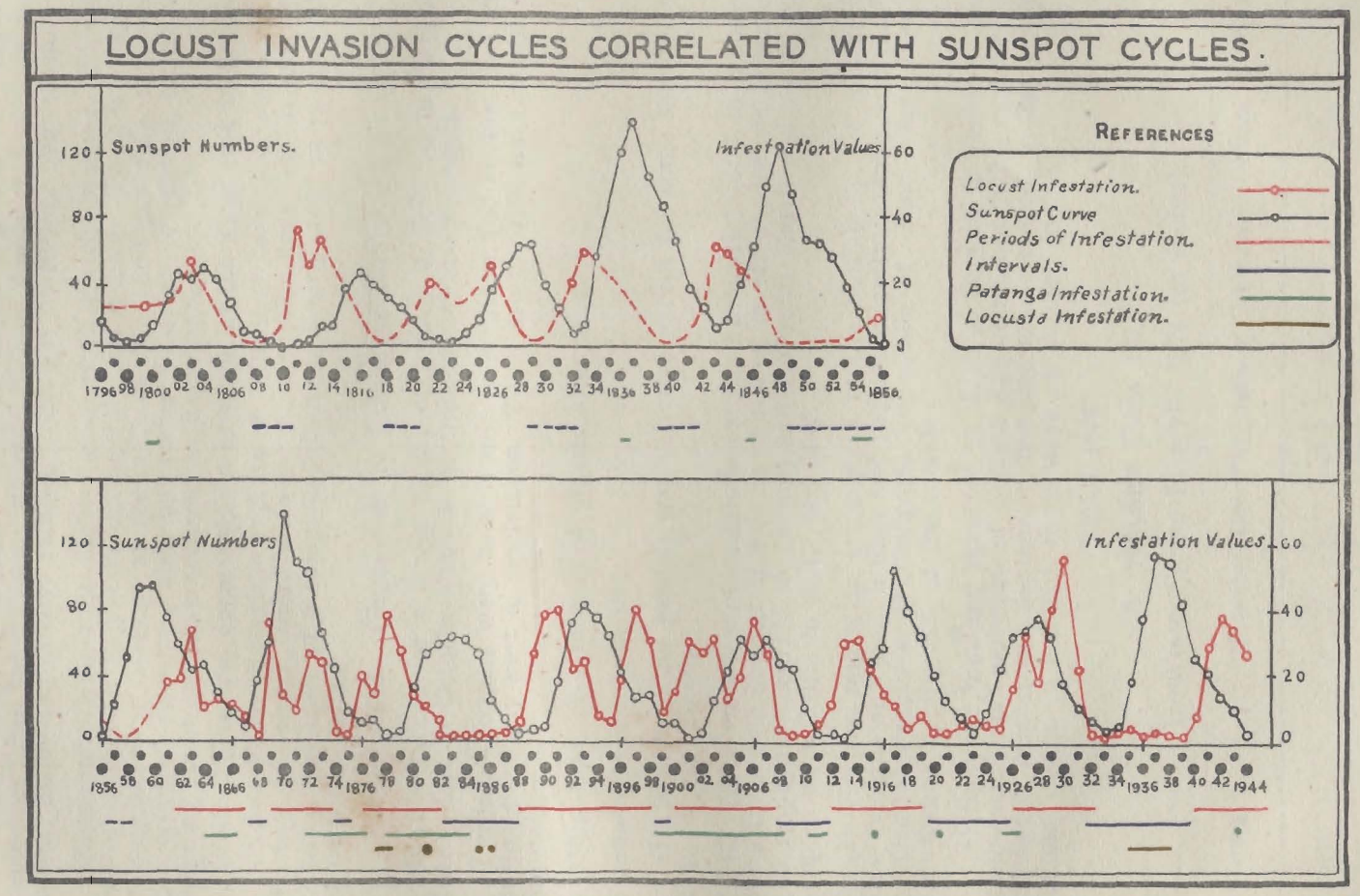
Sind. The first flights were note in Karachi and Hyderabad in the first week of June. Further flights were reported from these districts as well as from Shikarpur and Upper Sind Frontier in the course of the month.

Rajputana. The earliest reports are from Sirohi State, where locusts were noticed at the end of May or the beginning of June at Erinpura and Abu. Several flights were said to have been passing backwards and forwards in Marwar during the second and third weeks of June.

Punjab. Flights continued in June, being reports from Kohat, Hazara, and Amritsar. In July, they appeared in Shahpur, Gujranwala, Amritsar, Ludhiana, Montgomery and Ferozepur.

Central Provinces. During June, the weather was cloudy with westerly winds, and it was reported that locusts passed over Jubbulpore about the middle of June.

Bengal. According to the Commissioner of Burdwan, locusts are said to have passed over part of Burdwan district in 1873' (presumably at the end of June), ['Cotes, 1891 (a)]'



GRAPH SHOWING A CURVE OF FLUCTUATION OF SUNSPOT NUMBERS FROM 1796 TO 1944 WITH A SUPER-IMPOSED CURVE OF RISE & FALL OF LOCUST INFESTATIONS IN INDIA.

Summer breeding—Punjab. Hoppers were reported in August-September from the following districts Jhelum, Amritsar, Ludhiana and Hissar; owing to defective rainfall, there was no further oviposition.

Rajputana. Numerous flights occurred in Sirohi, Marwar, Bikaner and other parts of Rajputana during July and August. There is a report of oviposition in Marwar at the close of July, and probably egglaying had occurred elsewhere also, but owing to defective rainfall, extensive breeding could not have occurred in Rajputana.

Sind. There was apparently no breeding in the Thar area in Sind.

[*Note.*—From the season reports of 1873, it is seen that, owing to a shortage of rainfall, there were serious apprehensions of famine in Bikaner, and fears of a complete failure of *Kharif* crops in many parts of northern India.]

IV. *Autumn* 1873. (September to November 1873).

Sind. Except for a single report of locusts in Sehwan in Karachi district late in October, there is no information about locusts.

Punjab.—Hoppers were being found in Amritsar and Jhelum districts during the early part of September. There are no data for the rest of the year.

Rajputana. No records of locusts after August.

Summary of events in 1873

(1) Winter-spring rainfall was defective except for some showers in January and March.

(2) There were few overwintering swarms in north Punjab in January, but after a fair amount of rain in this area in March, locusts appeared and egglaying occurred in Jhelum and Kohat in March and April and hoppers were found in April and May.

(3) Western migration commenced in the Punjab by the middle of May, Swarms appeared in Sind and Rajputana early in June, and reached Central Provinces (Jubbulpore) by middle of June, and Bengal (Burdwan) by the end of the month.

(4) Summer breeding occurred in July to August in central and south-east Punjab and parts of western Rajputana, but owing to defective rainfall in August and September, few swarms developed, so that except for one swarm in Karachi, there were no autumn flights.

YEAR 1874

A. Weather Data 1874

I.—*Winter-Spring Rainfall*—1873 (*in inches*).

1873-1874	November	December	January	February	March	April
Karachi	..	0·43	0·54	0·10	..	..
Jacobabad	..	0·20	0·46	0·10	0·06	0·39
Multan	..	0·50	0·60	..	0·60	..
D.I.Khan	..	0·60	1·10	0·70	1·60	1·80
Hissar	..	0·20	0·40	..	1·00	..

Winter-spring rainfall in the Indian areas satisfactory.

II.—*Monsoon Rainfall* 1874 (*in inches*).

1874	May	June	July	August	September
Karachi	..	0·86	5·95	0·95	..
Umarkot	..	..	6·77	5·69	0·10
Nagar-Parkar	..	2·21	7·02	7·73	0·20
Bhuj	..	4·98	4·51	2·09	0·18
Jodhpur	..	0·13	0·03	4·83	1·05
Erinpura	0·70	1·38	9·01	5·07	1·64
Multan	..	0·20	7·70	0·60	..

A good monsoon on the whole.

B. Locust Data 1874.

I. *Winter* 1874. No data.

II. *Spring* 1874. No data.

III. *Summer* 1874—*Sind*. A few locusts were reported to have been seen in Jati in Karachi district during the last week of July.

IV. *Autumn* 1874. No data.

Summary of events in 1874

No information regarding locusts except for the find of a few locusts at Jati in July, presumably the usual western migrants, nor about summer breeding and autumn flights; presumably the locusts had reverted to the *solitary* phase during the year.

YEAR 1875

A. Weather Notes 1875

I.—*Winter-Spring Rainfall* 1874-1875 (*in inches*)

1874-1875	November	December	January	February	March	April
Karachi	..	..	0·05	0·41	..	..
Jacobabad	..	..	..	0·82	..	..
Multan	..	..	..	0·23	..	..
D.I.Khan	..	..	..	3·14	0·47	..
Hissar	..	..	0·10	2·10	..	..

Winter-spring rainfall defective except for some good rain in Punjab in February.

II.—*Monsoon Rainfall* 1875 (*in inches*)

1875	May	June	July	August	September
Karachi	..	..	3·74	0·10	2·70
Umarkot	..	..	8·46	3·80	0·33
Nagar-Parkar	..	0·22	7·86	8·66	0·41
Bhuj	..	0·10	3·85	0·52	1·24
Jodhpur	1·01	0·72	4·45	1·96	5·41
Hissar	0·30	0·40	4·50	5·90	11·80

Apparently a good monsoon.

B. Locust Data 1875

No reliable information.

CHAPTER III

PERIOD 1876—1882

YEAR 1876

A. WEATHER NOTES 1876

I—*Winter-Spring Rainfall* 1875-1876 (*in inches*)

1875-1876	November	December	January	February	March	April
Karachi	1·38	1·13	..	0·06	0·07	..
Jacobabad	0·52	0·07	0·20	0·02	0·26	..
Multan	0·22	0·16	0·23	0·35	0·14	..
D.I. Khan	..	0·62	0·24	0·33	1·00	..
Hissar	..	..	..	..	0·30	..
D.G. Khan	0·30	0·30	0·30	0·20	..	..

Winter rainfall began early; but was, on the whole, light; spring rainfall was in defect.

II—*Monsoon Rainfall* 1876 (*in inches*)

1876	May	June	July	August	September
Karachi	..	..	4·00	1·24	..
Umarkot	..	..	8·46	3·80	0·33
Nagar-Parkar	..	0·22	7·86	8·66	0·41
Bhuj	..	0·40	3·13	0·83	1·41
Jodhpur	..	0·61	4·69	7·86	10·63
Erinpura	..	..	6·00	4·40	14·15
Multan	..	1·19	3·30	1·83	..
Hissar	1·00	1·30	12·60	..	3·70

Generally good rainfall in July and August. Heavy falls in Jodhpur and Erinpura in September.

B. LOCUST DATA 1876

I. *Winter* 1875-1876. No data available.

II. *Spring* 1876. No data.

III. *Summer* 1876 (June to August 1876).

Summer flights—Sind.—The first swarm on record in the Season and Crop Reports for 1876 in Sind passed through Sehwan on 23rd June. At about the same time, locusts also appeared in Kohistan. Further flights occurred in July and August in various parts of Sind.

Punjab.—According to Cotes, locusts were found in Hissar district in July.

There is no information for other parts of Northern India. Winter rainfall in Sind would indicate that western disturbances started early and gave good rainfall in southern latitudes, so that it is quite likely that good winter rain had fallen in Oman and British and Persian Mekran. The swarms that appeared in Sind in June were presumably the result of spring breeding in those areas.

As the monsoon was fairly heavy in the desert, widespread summer breeding should have occurred in the desert areas of Thar and Marwar.

IV.—*Autumn* 1876. (September to November 1876).

Autumn flights—Sind.—From September onwards, several flights were reported in the various parts of Sind presumably passing westwards.

Punjab.—The occurrence of locusts was reported from Gurgaon in the 3rd week of October. According to records of the Loharu State, swarms were observed in the autumn months of 1876 in Loharu.

Western India States.—Crops would appear to have been damaged by locusts in the western parts of Cutch State during autumn.

Persian Baluchistan.—Floyer [1882] writes as follows on a locust flight seen by him on the 9th November 1876 at Jask in Persian Mekran: 'Coming to this place, we encountered one of those extraordinary migrations of locusts which have so often been described in the east. These insects were so thick as to produce a shade over the earth like that of a thin cloud. They were all of the red edible kind, and as fat as possible. They rapidly devoured the spring grass that covered the low-lying patches and the leaves of the shrubs fringing the water courses.' This swarm was possibly one of those coming from the direction of Sind.

Summary of events in 1876

(1) There was probably fairly good spring breeding in the western areas and summer flights were seen in Sind and Punjab in June-July.

(2) There was probably fairly good summer breeding in the desert areas of Thar and Mallani in August to September.

(3) Autumn flights were noticed in Sind, Cutch and south-east Punjab, and in Persian Mekran.

YEAR 1877

A. Weather Notes 1877

I.—*Winter-Spring Rainfall* 1876-1877 (*in inches*)

1876-1877	November	December	January	February	March	April
Karachi . . .	0·03	..	..	1·53	0·08	0·22
Jacobabad . . .	0·39	0·03	..	0·07	..	0·20
Multan . . .	0·39	..	0·28	0·60	0·16	1·07
D.I. Khan . .	0·04	0·03	1·92	1·64	0·02	2·03
D.G. Khan . .	1·10	..	0·80	0·40	0·70	0·40
Hissar . . .	..	..	0·20	1·70	2·00	1·07

Winter-spring rainfall fairly good: with intensification of precipitation in November, February and April.

II—Monsoon Rainfall 1877 (*in inches*).

1877	May	June	July	August	September
Karachi	..	..	..	..	0·16
Umarkot	0·40	..	..	..	3·85
Nagar-Parkar	1·10	0·99	1·87	..	3·45
Bhuj	..	0·80	0·03	..	11·39
Jodhpur	0·75	..	3·00	..	0·05
Erinpura	1·65	0·75	4·00	..	0·25
Multan	1·40	0·06	..	1·11	9·15
Hissar	2·30	3·50	2·40	0·50	..

In Sind, Rajputana and Cutch: monsoon was in great defect in July; and a failure in August: heavy rainfall in many places in September. A very abnormal type of rainfall, due to an unusual type of pressure distribution during the monsoon period.

B. Locust Data 1877

I. *Winter* 1876-1877. No data.

II. *Spring* 1877 (March to May 1877).

No data for March and April.

May 1877—*Summer flights—Sind.* The earliest record in Sind was during the third week of May, when they appeared in Hyderabad district (Guni with damage to rice seedlings), and in Karachi district (Mirpur Batoro on 20th May, Dadu on 23rd and Sehwan) and during the next week, in Naushahro taluk on the 24th in Hyderabad, and also in Kohistan, Jerruck and Tatta taluks and Dadu on 31st in Karachi.

Gujarat and Western India States. During the third week of May, locusts passed through Viramgam taluk in Ahmedabad district, and in the following week, visited Bajana and Dasada talukas in Wadhwan State.

Punjab. Large flights appeared in Rohtak district on the 27th May passing west to east, and reappeared on the 28th May. Heavy and unexpected rains recorded at this time.

III. *Summer* 1877 (June to August 1877)

Summer flights—Sind. Flights continued in Sind during June almost all over the province causing damage to cotton, jowar and other crops and defoliating trees in many places.

Punjab. Flights appeared in Gurgaon and Delhi on the 10th June and in Jhang during the last week of the month.

Rajputana. It is recorded that, on the 9th June, one of the heaviest sand storms known passed over Bikaner and on the next day a large flight passed over Bikaner from the north-west towards the south-east.

Central Provinces. Flights of locusts passed through Tahsil Huttra in Damoh district during the week ending 21st June.

Bihar. According to the Commissioner of Bhagalpur and Sonthal Parganas, locusts visited Monghyr and did considerable damage to crops [Cotes, 1891, a]. A flight was also observed in this year in the neighbourhood of Patna [Scott's Note], and a specimen obtained from it

on 1st July 1877 by Scott has recently been identified by Dr. Henri de Saussure as closely allied to the species *Acridium succinctum*' [Cotes 1891, a]. Apparently some mistake has crept in somewhere in regard to this observation, for, there are no authentic records of flights of the Bombay Locust east of the Central Provinces, although solitary individuals of this species have been collected from many places in the Ganges valley including Pusa. There is little doubt that the flight noted by Mr. Scott on the 1st July pertained to a swarm of the Desert Locust and that the solitary specimen of the Bombay Locust had been captured after the swarm had left the locality.

Summer breeding. In the Season and Crop Report of the Sind Official Gazette for week ending 20th June 1877, it is stated that in Upper Sind Frontier district 'young locusts were doing damage to *kharif* crops on the Desert Canal.' As there was no rainfall in this area during May or June, it is more likely that by 'young locusts', it is *not locust hoppers* that are referred to, but only the *young ones of the black headed cricket* which is a common pest of these areas. Rainfall was greatly in defect in July and August not only in Sind but also in the Punjab, the United Provinces, and Central Provinces, on account of a certain abnormal type of pressure distribution in Northern India. Consequently there was apparently no breeding either in the Punjab or in most parts of Rajputana. Very few swarms were met with in Sind during July and August, and in Rajputana, there is a record of only one swarm that passed over Marwar in the third week of July. In the Punjab, swarms were reported in July from Lahore, Jhang, Hissar, Gurdaspur and Gujranwala, but none after that month.

IV. *Autumn* 1877 (September to November 1877)

In September heavy rain fell in most parts of India in north, as well as in south India and further rain in October. There are no data to indicate how the locusts left in the country reacted to the rainfall of September-October. It is possible that light breeding had been brought about in Rajputana or in north Gujarat.

Though there are no data for Northern India, there are some records of Locust activities in the Madras area.

The Collector of Cuddapa reported in his letter dated 8th November 1877: 'flights of insects, which appear to be locusts, and which, wherever they settled, entirely destroyed the crops, made their appearance in Pulivendla and Cuddappah talukas about 20 days ago (probably about 19th October), and when on the crops they are so thick as to look like a red cloud.' In a later letter (November), it was stated that the lower leaves of "Cholam" (*Sorghum*) crop had all been eaten up by *midthalu* (grass-hoppers or hoppers).

'Ragi' (*Eleusine*), 'Korra' (*Setaria*) and 'Cholam' (*Sorghum*) are said to have been attacked but the cotton and indigo crops left untouched.

From the Season and Crop Report for week ending 4th December 1877 of the Gazette of India, it is seen that 'Varagu' (*Paspalum*) crops of Bapatla and Narasaraopet talukas had been attacked by locusts some time back.

It is not possible to say which species of locusts is referred to in the above data. The remark made about 'red locusts' might be referable either to the pink swarms of the Desert Locust or to those of the Bombay Locust. In the year following (1878), the desert locust actually visited the Ceded Districts, Nellore and Kistna at about this time, but unlike 1878, there are no definite clues by which they could be traced to their sources of origin in North India, as has been possible for the yer 1878. On the other hand, a study of the wind movements during the latter part

of September shows that, as a result of the abnormal developments of year 1877, north-easterly, northerly or northwesterly winds were current in the region between the Central Provinces and Southern India, so that the wind direction was favourable for the passage of swarms from north to south. During October 1877, there was an extension of the south-west monsoon beyond the usual time in South India, so that south-westerly winds were prevalent in north Madras instead of the normal north-easterlies.

There is reason to doubt if the species in question could have been the 'Bombay Locust', as there is no authentic record of this species visiting the Madras areas at any period other than during May and June. In the absence of further data, no definite opinion can be expressed in regard to the exact significance of these data.

Summary of events in 1877

(1) The winter-spring rainfall was apparently favourable for the development of spring breeding in the western areas.

(2) Western flights commenced about the middle of May and were noticed in Sind, Punjab and north Gujarat.

(3) In June, the flights reached Damoh district in Central Provinces and Bihar by the end of the month.

(4) Owing to an abnormal type of pressure distribution, there was a failure of rainfall in July and August in most parts of Northern India and consequently there was no summer breeding.

(5) There were no autumn flights in northern India, but there are some records of the occurrence of locusts in the Cuddappa and Kistna districts of Madras in October—November, but it is not possible to decide about the species of locust concerned in the absence of additional data.

YEAR 1878

A. Weather Data 1878

I—Winter-Spring Rainfall 1877—1878 (*in inches*).

1877-1878	November	December	January	February	March	April
Karachi	0·02	0·03	0·29	0·31	..	..
Jacobabad	0·86	0·51	0·05	0·58	..	0·10
Quetta	?	?	0·63	3·40	0·64	0·98
Kalat	1·16	1·87	0·80	4·09	1·00	0·23
Multan	0·22	1·43	0·06	0·58	..	0·26
D.I.Khan	1·78	1·99	0·22	1·55	0·23	2·62
D.G.Khan	0·20	1·30	..	0·50	..	0·60
Hissar	0·90	1·20	0·70	0·50	..	1·20

Western disturbances had apparently commenced early in the season and would appear to have been generally productive of rainfall.

II—Monsoon Rainfall 1878 (*in inches*).

1878	May	June	July	August	September
Karachi	..	0·07	11·25	11·26	0·65
Umarkot	..	0·43	2·05	0·29	0·74
Nagar-Parkar	0·12	0·04	6·67	7·33	2·16
Bhuj	..	10·85	12·73	7·72	4·27
Jodhpur	0·50	1·25	8·10	9·24	0·35
Bikaner	3·34	1·77	5·49	5·62	..
Erinpura	0·60	0·65	7·60	10·00	0·75
Multan	0·83	0·33	3·75	4·05	..
D.I.Khan	1·12	1·50	2·65	6·29	0·03
Hissar	1·70	1·40	4·30	10·66	..

Monsoon commenced early: heavy rainfall occurred in July and August in most places: there was fairly good rain even in September in the desert areas.

B. LOCUST DATA 1878 (*vide* Pl. 59)

I. *Winter* 1877—1878 (December 1877 to February 1878). No data.

II. *Spring* 1878 (March to May 1878).

No data for March and April; apparently there were no overwintering swarms anywhere.

May 1878.—The earliest report of locusts is found in the Season Report for week ending 28th May 1878, indicating that locusts had passed over Hyderabad on the 28th May flying east to west. They were found feeding the next morning on Babul (*Acacia*) in the neighbourhood.

III. *Summer* 1878. (June to August 1878).

Summer flights—Sind. The flights that began at the end of May, continued throughout June and July, visiting almost all parts of Sind and causing damage to crops and trees.

Rajputana. The earlist record in Rajputana is that of the 9th June, when swarms were reported from Ajmer and Merwara. During the following week, they were found passing over Bikaner (10th June) south to north and in Marwar.

Punjab. Locusts were reported from Delhi tahsil during the last week of June.

United Provinces. By the middle of July, damage by locusts was reported from Garhwal, Basti (83°E. Long.) and Sultanpur.

Central Provinces. Locusts passed over Mandla (81°E. Long.) on the 9th and the 13th June.

Orissa. From information recorded in Proceedings of the Board of Revenue Madras, it is seen that flights occurred between the 8th and the 17th June in Balliguda Maliahs (Ganjam district) at several places, generally coming from the west from Kalahandi State and passing eastwards. *Jowar,* millets, paddy, and *ragi* were attacked. On the 17th and 18th June, other swarms were reported to have come from Sarungada of Chinnakimedi and to have passed over Koinjur of Goomsur Maliahs in a north-east direction into Baud. Gingelly, millets and young paddy were destroyed and Jak and Drumstick trees were stripped.

Summer breeding. Migration from the west continued in July in Punjab, Rajputana and United Provinces. Locusts presumably also reached Kathiawar and north Gujarat in July and damage to growing crops by locusts (possibly hoppers), was reported in August from various places in Wadhawan and Badhanpur areas (Jhinjuvade, Patri, Wanod). Breeding is reported to have occurred in the Punjab and in Rajputana.

Punjab. Hoppers were noticed warming during July and August in Hissar and Rohtak districts and were being destroyed.

Rajputana. Young locusts were reported from Ajmer, Sirohi and Alwar areas. Although not specifically recorded there is little doubt that breeding had occurred all over east and west Rajputana as the rainfall was heavy and widespread, though perhaps breeding was likely to have been adversely affected by excessive moisture.

Sind. There is no mention of breeding in the season reports, but it probably occurred not only in Thar but also in Karachi and Lasbela areas, where heavy rain had fallen in July and August.

IV. *Autumn* 1878 (September to November 1878)

Late summer breeding—Punjab.—Swarms visited Hazara district in the latter part of August and would appear to have laid eggs in September. Hoppers were found in the district during October.

Western India States and North Gujarat.—Heavy ranfall received in September would appear to have favoured breeding and young hoppers were reported from some of these areas in October and November—Wadhwan, Jhinjhunwada, Patri and Bhoika, and also in Ahmedabad and Broach areas. The following statement is extracted from the *Gazetteer of the Bombay Presidency,* Vol. VIII—Kathiawar: 'In 1878. the crops were devoured by locusts of many shades: red, yellow, pink, brown and green. Of these, the red and yellow were the most common. These locusts were destroyed by the heavy rain, but not until they had laid eggs from which the young locusts were hatched and for a short time devastated the cold weather crops.' Possibly all the three species of locusts: *Schistocerca* (red and yellow), *Patanga* (Pink) and *Locusta* (brown and green) had been breeding in this area during the period above referred to.

Autumn flights—Sind.—From September onwards, numerous flights were reported from almost all parts of Sind, causing damage to crops. Some of these were apparently quite large ones and in one case, a swarm observed in Karachi on the 19th November is said to have been driven seawards by a strong easterly breeze. During week ending 23rd October, large flights were observed in Upper Sind Frontier district at Jacobabad and at about this time flights were noted by Capt. Reynolds of the Baluchistan Administration passing over Dera Bughti in Marri-Bughti country. Apparently all these flights were directed towards Baluchistan and Iran.

Punjab.—Numerous flights were noticed in parts of the Punjab during autumn. In December, locusts were found in great numbers in the hill areas of Kangra.

Rajputana.—Damage to crops was reported from parts of Rajputana in October, November and December.

Central India.—Locusts appeared in Barwani in September 1878 flying north to south.

Central Provinces.—During the latter half of September, locusts appeared in Saugor district, and towards its close, they were reported moving eastwards from Balaghat district towards Raipur. Early in October, swarms were reported from Hoshangabad, Narsingpur and Jubbulpore, flight direction being west to east. They also appeared in Malkapur taluk of Amraoti district in Berar on the 9th October. During the 2nd week of October, locusts passed through Betul into Berar. During the succeeding weeks of October and in November, flights were observed in Jubbulpore and Seoni districts.

United Provinces.—With the withdrawal of the monsoon, hot westerly winds commenced to blow on the Gangetic plain and locust flights would seem to have accompanied them. During October, locust damage was reported from Agra, Allahabad, Partabgarh and Benaras, and doubtless the whole of the province had been invaded by locusts by the end of October.

Bihar.—During the week ending 29th October, flights of locusts were reported from Sarun and Buxar (Shahabad district), and also from Champaran. Early in November, ravages of locusts were reported from Lohardagga and from Sonthal Parganas.

Orissa.—From the Proceedings of the Madras Revenue Board, it is seen that swarms made their appearance early in September, 1878 in Sreerampur taluk Goddapore Estate in Goomsur Maliahs, in Ganjam. They are said to have come from the south and to have departed in a westerly direction after damaging paddy and maize. Apparently these should have come from east Central Provinces.

Bengal.—Swarms reached Bengal by the beginning of November. In the north, Dinajpur and Cooch Bihar were infested, mustard and paddy being attacked. The general direction of flight was south-west to north-east. In the south, Murshidabad, Bankura and Nuddea were visited and towards the east, Jessore, Dacca, Tipperah and Hill Tipperah (92°E. Long.). Various crops such as mustard, chillies, tobacco and radish were damaged.

Western India States and North Gujarat.—Swarms were seen during September in Wadhwan, Rajkot, Ahmedabad and Kaira areas and spread in October and November into Broach, Baroda and Surat. Several swarms were found in Kathiawar and Gujarat areas even in December.

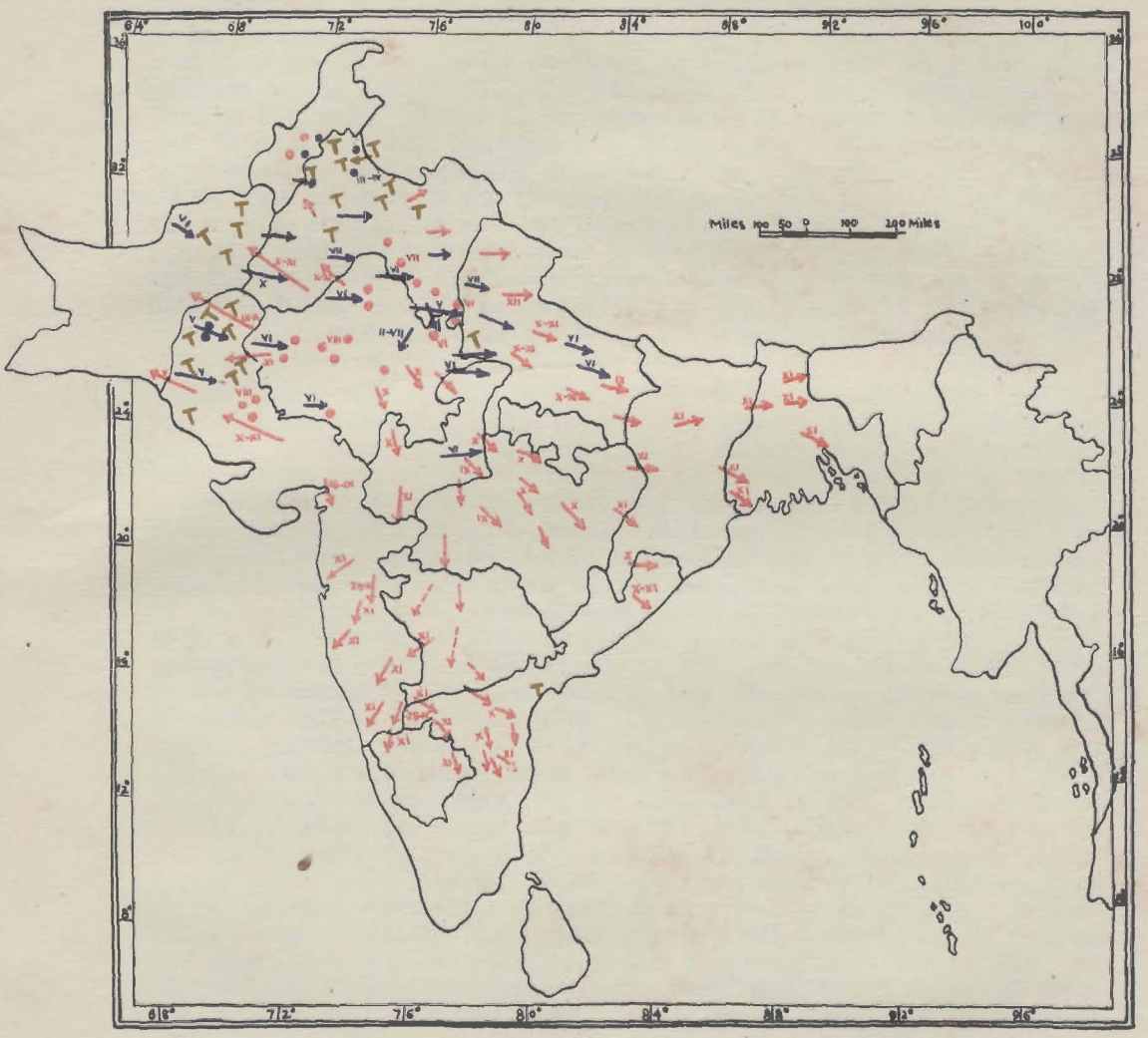
Bombay Presidency.—As already mentioned, swarms had reached Barwani in September and during the first week of October had passed through Nimar into Malkapur and Amraoti in Berar. By the beginning of October, Swarms appeared in Khandesh, and during the succeeding week, they were reported from Ahmednagar and Nasik, apparently appearing here from the direction of Berar. During the 3rd and 4th weeks, flights were found in Poona, Sholapur, Satara, Belgaum, Dharwar and Bijapur (Kaladgi). During November swarms reached Thana and Kolaba.

Madras.—Between the 16th and the 27th October, swarms of red locusts, (as recorded in Proceedings of the Board of Revenue, Madras), would appear to have visited various talukas of Bellary and Anantapur districts: Anantapur, Kalyandrug, Hospet, Rayadrug, Bellary, Adoni and Siruguppa. The general direction was west to east and various cereals and garden plants were attacked.

On the 16th November, large flights appeared in Muktyala, Nandigama and Vissannapet areas of Kistna district from the Nizam's territory. Another swarm came on the 7th November from Kondavid hills into Tenali and Repalli and departed towards Divi area. Locusts also visited towards the end of November, the Narasaraopet, Bapatla, Repalli and Bunder talukas, where they destroyed recently sown 'variga' or 'varagu'. On the 18th and 19th November, flights were reported from Kandukur, Kavali and Ongole talukas of Nellore district, the direction of flight being north to south. Towards the beginning of December, a flight crossed into Divi villages from Kondavid side and it is stated that 'millons of the locusts perished from wind and cold and the residue possibly driven out to sea during the recent gale'. From the meteorological records it is seen that the gale referred to was connected with a severe cyclonic storm which crossed inland in the Kistna area on the 6th and 7th December 1878.

A study of the meteorological data recorded in the Indian Daily Weather Charts has proved very interesting, as the somewhat extraordinary movements of the swarms in the autumn, leading to the spread of flights as far as Tipperah in the east and as far as Dharwar, Bellary and Nellore in the south would appear to be closely related to the changes in the wind movements dependent on weather developments.

In regard to the flights observed in the Balliguda Maliahs in Ganjam (of the present Orissa province), between the 8th and the 18th June, it



LOCUST SITUATION IN INDIA IN 1890

had made certain statements in an earlier publication [Rao, 1943], which, in the light of the further studies made recently, he has found not quite warranted. For instance, he had therein considered reports of an invasion of pink coloured locusts in Bellary and Kistna in October—November to have been concerned with the Bombay Locust, and the

is found that owing to the development of low pressure areas in Eastern Central Provinces on the 10th, the 13th and the 15th, the normal north-westerly winds had curved, at the latitude of southern Central Provinces, into south-westerly currents in the Ganjam area.

As to the movements of swarms in Central Provinces in the autumn months, the normal winds are westerlies and would, as a rule, convey the flights eastwards into Bihar, Orissa and Bengal.

In the last week of September under the influence of a low pressure area over the Mekran coast, northerly or north-easterly winds had been induced over north Gujarat, Central India and the western parts of Central Provinces, leading to the movements of swarms into Kathiawar and Gujarat and into Barwani and Nimar areas. From October 7th north-westerly winds passing south-east almost parallel to the Western Ghats were common in the Bombay and Hyderabad areas till the end of the month, alternating with north-easterlies. These winds were instrumental in taking the swarms down to the Dharwar areas and into Bellary and Kistna districts. In November and December of the directions of flights in Kistna and Nellore were presumably determined partly by the normal north-easterlies and partly by the wind developments connected with a cyclonic storm early in December.

Locust invasion of 1878 in Madras.—It should be mentioned that the year 1878 was remarkable also for the very unusual and the rather extraordinary development of an outbreak of *Locusta migratoria* in South India, an account of which was given by Cotes [1891, a] in an article in the Indian Museum Notes in 1891 and recently also by the writer [Rao, 1943]. Usually this locust is found distributed all over India in its solitary phase form, but under the influence of certain very abnormal conditions of weather brought about by the drought of 1876 to 1877, followed by the unusually late though heavy rains of September to November 1877, would appear to have developed into a serious pest of the first magnitude. The earliest occurrence of breeding was observed in parts of the Trichinopoly, Madura, Ramnad and Tinnevelly districts between December 1877 and February 1878. Locust swarms were first noticed in Madura district, which began to fly north-wards into Coimbatore and Malabar districts during March. Breeding occurred in parts of these districts in April and May. In the meantime, further flights directed northward over the Nilgiri and Satyamangalam Hills took the swarms into the western districts of Mysore (Mysore, Kadur, Hassan and Chitaldroog) and thence into the western parts of Bellary into Dharwar and south Belgaum. Breeding occurred in April—May in parts of Mysore and Bellary. With the appearance of the south-westerly winds in May and June, the swarms moved into the eastern districts of Mysore and Madras, *viz.*, Kolar, Bangalore, Salem, Cuddappa, North Arcot, Chingleput and Nellore in the north, and Tanjore, South Arcot and Trichinopoly in the south. There was but little breeding in the south-west monsoon period and the swarms gradually diminished in number, and as the rains of the north-east monsoon also proved defective, there was no further multiplication and the outbreak came to an end by the close of the year.

It is thus seen that in the southern parts of the Indian Peninsula, two species of locusts were active during the year 1878. In regard to the identity of the species, concerned in the data of this period, the writer had made certain statements in an earlier publication [Rao, 1943], which, in the light of the further studies made recently, he has found not quite warranted. For instance, he had therein considered reports of an invasion of pink coloured locusts in Bellary and Kistna in October—November to have been concerned with the Bombay Locust, and the

species referred to in the reports of locust movements in June and September in the Ganjam Maliahs to have been possibly, *Locusta migratoria.* A full study of the locust movements all over India in 1878 has, however, shown conclusively that the above data are all referable to the activities of Desert Locust.

Summary of events in 1878 *(vide* Pl. 59).

(1) Winter-spring rainfall was apparently favourable for spring breeding in the western areas, but there was no overwintering in India.

(2) Summer flights commenced by the end of May and continued during June and July. They reached as far east as the Ganjam coast by the middle of June and Sultanpur district in the United Provinces.

(3) Summer breeding occurred presumably all over the desert areas and in parts of the Punjab. Owing to heavy rainfall in September, late summer breeding occurred in the Hazara district of the Punjab and in *north Gujarat and Kathiawar.*

(4) Extensive autumn flights occurred, part of which was directed west into Sind and Punjab; part, eastwards over Central Provinces into Bihar and Bengal as far as Hill-Tipperah and part southwards into North Gujrat and Kathiawar, into Bombay as far south as Dharwar and into north Madras as far as Bellary, Anantapur, Kistna and Nellore.

(5) In 1878, an extensive outbreak of *Locusta migratoria* occurred in South India. The main breeding was in the southern districts in the months of January-February-March and the swarms spread during the spring months north into Coimbatore and Mysore and reached as far as Bellary, Dharwar and south Belgaum by May. The swarms then spread to the eastern districts of Madras during the months of June, July and August and ultimately died down by the end of the year.

YEAR 1879

A. Weather Data 1879

I—Winter-Spring Rainfall 1878-79 *(in inches)*

1878-1879	November	December	January	February	March	April
Karachi	..	..	.	..	1·00	..
Jacobabad	..	..	..	..	0·68	..
Quetta	..	..	0·18	1·61	1·46	0·26
Kalat	..	..		1·49	3·36	..
Multan	..	..	..	..	1·73	..
D.I. Khan	..	..	..	..	1·55	..
Hissar	..	..	..	0·10	0·30	..

Winter-Spring rainfall was evidently in defect except for some amount of precipitation in March.

II—Monsoon Rainfall 1879 *(in inches).*

1879	May	June	July	August	September
Karachi	..	0·04	..	0·87	0·01
Umarkot	0·06	1·67	0·30	1·37	1·63
Nagar-Parkar	0·05	3·85	2·15	7·96	0·70
Jodhpur	..	3·94	0·03	5·29	0·40
Bhuj	..	0·88	0·15	7·19	1·95
Erinpura	..	4·05	1·15	8·60	0·70
Bikaner	0·66	6·41	0·14	6·30	3·02
Multan	..	1·32	0·81	1·03	..
Hissar	0·20	0·90	0·40	7·30	1·40
D.I. Khan	0·16	0·18	2·06	1·07	0·10

Monsoon began with good rain in June. There was heavy rainfall in August and some rain in September.

B. LOCUST DATA 1879.

I. *Winter* 1878-79 (December 1878 to February 1879).

Swarms were reported from many parts of north India during the winter months.

In Sind Swarms were active in most parts of the province up to the middle of February.

In *Punjab*, swarms were reported from Jhang and Dera Ismail Khan and in *Rajputana*, from Ajmer and Sirohi in February. In *Western India States*, flights were reported from Kathiawar, Ahmedabad, Kaira, Panch Mahals and Broach, during January, but would seem to have disappeared by the beginning of February. In the *United Provinces* swarms were active in Kumaon during February. In *Bihar* large flights are said to have passed through Muzaffarpur district.

II. *Spring* 1879 (March to May 1879).

There were no locusts in North West India during March and April, except in Punjab and United Provinces.

Punjab. Locusts were reported from Hazara, Jhelum and Rawalpindi during March and April. According to Cotes [1891], flights were reported in Hissar district in April coming from the direction of Rajputana.

United Provinces. According to the Season Reports of the *Gazette of India* swarms were present in March in Kumaon and also in Meerut where 'locusts had done some harm.' Cotes mentions that 'in 1879, according to a note published in the Proceedings of the Entomological Society of London, locusts appeared early in March in Meerut, covering a tract of country 15 miles long by two or three miles broad, and gradually moved northwards up the Anupshahr branch of the Ganges Canal. They laid eggs over the whole area, and before the end of the month, the whole ground was covered with little black larvae. Considerable damage was done to the peas and mustard, but not to the grain which was then being cut,' [Cotes 1891].

Western flights. The first report of flights from the west in Sind is from Nasirabad in Shikarpur district on the 18th May.

III. *Summer* 1879 (June to August 1879).

Summer flights continued in *Sind* in June and July, and in *Rajputana* swarms were reported from Marwar and Ajmer in July. Apparently, flights reached the *Western India States*, in June, for in the 3rd week of July *young locusts* were said to be damaging crops in Central Kathiawar. As there was heavy rainfall in June in these areas, oviposition would appear to have been induced. As good rainfall is recorded in south Marwar and Bikaner also in June, it may be presumed that early breeding had similarly taken place in parts of the Rajputana Desert. As good, and even heavy, rainfall occurred in August after a considerable break in July, it is likely that further breeding had been induced in the Rajputana areas.

In the *Punjab*, swarms were reported from Gurgaon, Hissar and Dera Ghazi Khan, but there is no information regarding breeding.

IV. *Autumn* 1879 (September to November 1879).

Autumn flights. Numerous swarms were reported from all parts of *Sind* during September, October, November and December, as well as damage to various *rabi* crops. In *Punjab*, a few flights were reported in November-December from Muzaffargarh and Dera Ismail Khan districts. In *Rajputana*, a few flights in Marwar were recorded and in *United*

Provinces, a few swarms in Kumaon district. In the *Bombay Presidency*, swarms appeared in November in the Broach, Surat, Baroda and Nasik areas. According to the *Ahmednagar District Gazetteer* [1884], a swarm of locusts with bright red underwings came from the north in October 1879 and passed south after eating up the ear heads of the millet crops. It appears very likely that the data relating to the above Bombay areas are referable to the Bombay Locust and not to *Schistocerca*.

Summary of events in 1879

(1) Winter-spring rainfall was apparently in great defect except for rainfall in March.

(2) Overwintering swarms were found in Sind, Punjab, United Provinces and Gujarat.

(3) Spring breeding occurred in Meerut in United Provinces along the Anupshahr branch of the Ganges Canal; but nowhere else.

(4) Western flights occurred in May-June and reached the Western India States, where breeding occurred after rainfall in June. Breeding also occurred in parts of the Rajputana desert between July and September.

(5) Numerous autumn flights were noticed in Sind, but comparatively few in Punjab, Rajputana and United Provinces.

(6) Swarms reported, in October and November, in Broach, Surat, Baroda, Nasik and Ahmednagar districts were probably those of the Bombay Locust.

YEAR 1880

A. Weather Notes 1880

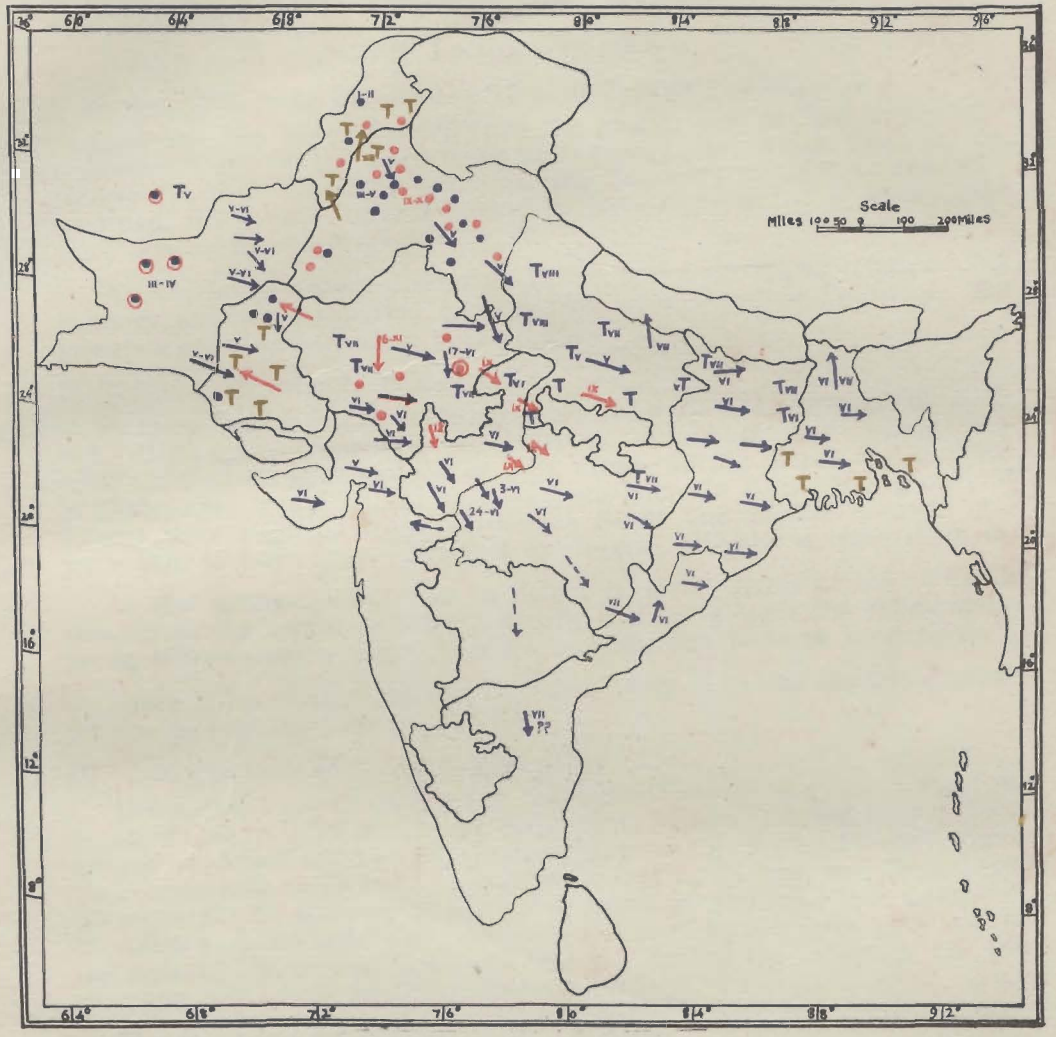
I —*Winter-Spring Rainfall* 1879—1880. *(in inches)*

1879-1880	November	December	January	February	March	April
Karachi	..	..	..	0·21	..	.
Jacobabad	..	..	..	0·65	..	.
Quetta	..	..	0·25	0·35	0·90	9·18
Multan	..	..	..	0·46	..	..
D. I. Khan	..	0·04	0·04	0·03	..	..
Hissar	..	2·00	..	0·30	..	..

Rainfall was apparently in great defect except for light showers in February.

II—Monsoon Rainfall 1880 *(in inches)*

1880	May	June	July	August	September	October
Karachi	..	..	..	..	3·88	..
Umarkot	..	0·93	0·70	0·43	2·36	..
Nagar-Parkar	..	0·40	1·95	2·97	2·80	2·62
Bhuj	..	0·53	0·83	0·17	4·44	3·04
Jodhpur	0·02	0·64	1·90	4·74	1·19	0·12
Erinpura	..	0·15	4·00	5·80	2·05	1·30
Pachpadra	..	1·03	1·93	6·03	1·26	0·14
Bikaner	0·35	1·71	3·82	2·61	0·58	0·05
Multan	..	0·97	2·25	0·20	0·62	..
Hissar	..	2·40	7·30	1·70	1·30	..
D. I. Khan	..	..	1·27	1·80	0·41	..



LOCUST SITUATION IN INDIA IN 1891

Surgeon-Major Hendery in Jaipur State in [illegible] a mistake, and it is very likely that the year under reference was really 1881, during which there was a heavy visitation of locusts in N. W. India.

IV. *Autumn* 1880 (September to November 1880)

No data from any part of North West India.

Summary of events in 1880.

(1) Winter-spring rainfall was greatly in defect; and presumably no spring breeding in any of the western areas.

(2) Swarms were found in January in Punjab and Sind.

In Sind., the monsoon was more or less a failure except for good rain in September; in Rajputana, however, there was better rainfall in June, July and August.

B. LOCUST DATA 1880

I. *Winter* 1879—1880 (December 1879 to February 1880).

Sind. Swarms were reported from the greater part of Sind apparently migrating west, till the third week of January, after which there are no records for the rest of the year. During February when light rain was recorded, the country would appear to have experienced a severe cold were accompanied by frosts.

Punjab. Locusts were present in Bannu and Dera Ismail Khan during January and were reported from Sialkot at the end of February. No locusts were found in other parts of N. W. India.

II. *Spring* 1880 (March to May 1880).

Punjab. Locust flights were reported from Hazara, Rawalpindi, Sialkot, Gurdaspur, Amritsar, Hoshiarpur, Jullundur and Simla districts--almost all sub-montane or hilly areas—during March and in some of these, eggs would appear to have been laid. In April, young ones of locusts were reported from Gurdaspur, Simla and Sialkot districts and were said to have been destroyed by digging pits and driving them in.

As the spring-rainfall was in defect in most parts of the Punjab swarms would appear to have gradually drifted towards the submontane areas, where usually there is more rainfall, and to have bred there.

There is no further information about locusts in the Season Reports for the rest of the year.

III. *Summer* 1880 (June to August 1880)

There are no data indicating the occurrence of the usual summer flights either in Sind, Punjab or Rajputana. Winter Rainfall having been greatly in defect for two consecutive years (1878-79 and 1879-80), there was apparently no breeding whatever in spring in Iran and Oman, and consequently no summer flights. It is possible, however, that migration of solitary individuals had occurred, followed by *solitaria* breeding in the desert. There was little rain in Thar during the monsoon, but the situation was better in the Rajputana areas.

The following remarks occur in the Reports of the Political Administration of Rajputana for the year 1880-1881:—'*Western States Agency Report*: 'Rainfall defective in many parts. *The country free from locusts this year*', *Eastern States Agency Report*: 'Rainfall below average. *No damage by locusts* or hailstorms.' It is therefore evident that there was no locust visitation in Rajputana during 1880. The statement made by Cotes [1891] in regard to the considerable damage reported by Surgeon-Major Hendely in Jaipur State in 1880 is, therefore, apparently a mistake, and it is very likely that the year under reference was really 1881, during which there was a heavy visitation of locusts in N. W. India.

IV. *Autumn* 1880 (September to November 1880)

No data from any part of North West India.

Summary of events in 1880.

(1) Winter-spring rainfall was greatly in defect; and presumably no spring breeding in any of the western areas.

(2) Swarms were found in January in Punjab and Sind.

(3) In March, most of the swarms concentrated in the sub-montane districts of the Punjab and a certain amount of breeding occurred in Sialkot, Gurdaspur, Simla and Jullundur.

(4) Apparently no western migration in summer and no breeding in Rajputana.

(5) No information regarding locusts in autumn.

YEAR 1881

A. Weather Notes 1881

I—*Winter-Spring Rainfall* 1880—1881 (*in inches*)

1880-1881	November	December	January	February	March	April
Karachi	..	..	..	0·08	0·35	4·75
Jacobabad	..	0·11	..	0·17	0·12	0·14
Quetta	..	2·97	0·13	2·57	2·82	2·35
Multan	..	0·57	..	0·59	0·70	0·0
D. I. Khan	..	0·83	0·05	0·46	1·70	2·45
Hissar	..	0·70	..	0·30	0·70	1·50

Winter-spring rainfall apparently good in the Punjab and Baluchistan, and presumably so in south Iran and in Oman.

II—*Monsoon Rainfall* 1881 (*in inches*)

1881	May	June	July	August	September
Karachi	..	0·04	1·71	2·04	1.05
Umarkot	..	..	2·82	5·77	1·94
Nagar-Parkar	..	0·18	11·74	6·99	3.21
Bhuj	..	..	10·19	2·75	2.24
Jodhpur	0·93	0·12	4.81	14·63	1.83
Pachpadra	0·76	0·22	2·20	7·06	5·39
Pirnpura	..	0·20	10·25	6·20	3.30
Bikaner	6·95	0·73	7·80	2·47	0.52
Multan	0·03	0·03	1·25	1·70	..
D. I. Khan	..	1·65	1·37	1·43	..
Hissar	0·10	0·20	7·50	5·70	0 10

Heavy rainfall in July and August except in such Sind and west Punjab. Fairly heavy falls in south Rajputana in September.

B. Locust Data 1881

I. *Winter* 1881—(December 1880 to February 1881)

No overwintering swarms anywhere.

II. *Spring* 1881—(March to May 1881)

No information about locusts for March and April.

Western flights commenced, appearing in Sind from the week ending 11th May 1881. They were seen in Tatta taluk of Karachi district and in Hyderabad. Several swarms were reported from Karachi, Hyderabad and Shikarpur districts in the course of May.

III. *Summer* 1881—(June to August 1881)

Sind. Numerous flights were recorded from amost all part of Sind damaging the leaves of trees in many places.

There are no data for the United Provinces, and in the case of the Punjab, the only item available is the appearance of flights in Dera Ghazi Khan in July-August 1881 damaging *kharif* crops.

In the Western India States and North Gujarat, locusts appeared at Kapadvanj in Kaira district during week ending 6th July 1881 for 40 minutes and passed off towards Modasa. It is likely that other flights had appeared in Kathiawar and Palanpur eariler but had not been reported.

In *Rajputana,* the earliest flights on record in the Season Reports were for the week ending 8th July in Marwar. There is little doubt, however, that the swarms that had appeared during May in Sind had passed over Rajputana without being reported.

In a report dated the 14th July 1883, submited by W.H. Grimley to the Bengal Government, it is stated that 'a swarm of locusts with heads and wings of a red colour visited the Gobindpore sub-division of Manbhum district of *Bihar and Chota Nagpur* in June, 1881, and destroyed young *dhan* seedlings and just sprouting Indian corn and *gondlee*. The swarm is said to have been 10 miles by 5 miles and about a quarter of a mile high, and to have emerged from Laghu Pahar and Paresnath Hill in the Hazaribagh district' [Cotes 1891 a]. In this case, Cotes was of opinion that this flight was *not one of Acridium peregrinum* (*Schistocerca gregaria* Forsk), but might probably have been either a swarm of local origin in Manbhum, or one belonging to the species *Acridium succinctum.* The main argument adduced against the desert locust in this instance, as well as in the case of the years 1862, 1865, 1873, 1877 and 1878, however, was that this locust was *not known* to have been prevalent in its regular breeding grounds in North Western India during these years. The writer had, in an earlier publication, [Rao, 1943] acquiesced in the opinion expressed by Cotes and had considered that most of the flights of the years mentioned were probably referable to the Bombay Locust. However, after collecting further data for these years and studying the movements of swarms year by year by charting them on maps, he has had to revise his earlier conclusions. The present studies have clearly proved that swarms of the Desert Locust are capable of progressing eastwards very rapidly over the plains of North India, during May and June, under the influence of the dry westerly winds, which are usually prevalent at this period, and there is little doubt that this is the species concerned in every case.

Summer breeding. During the third week of July, it was reported that locusts had settled down in sandy districts in Marwar and had laid eggs. During August, locusts were reported in various places in the Marwar State. According to Surgeon-Major Hendley, a large flight was observed by him in Jaipore by which considerable damage was done. Trains were also said to have been held up by the dead bodies of locusts on the Rajputana-Malwa Railway, [Cotes 1891].

There was heavy rainfall in August and September in Rajputana and it is possible that breeding had been adversely affected by the excessive moisture.

IV. Autumn 1881—(September to November 1881).

The only indication of *autumn flights* is the record in the Sind Season Report for the week ending 21st September of the appearance of locusts in Kandiaro, Hyderabad district.

In *Rajputana,* in the season report for week ending 27th September 1881, it was stated that 'locusts were little heard of.'

There is no other information regarding locusts for the rest of the autumn.

Summary of events in 1881.

(1) Winter-spring rainfall being favourable, probably breeding had occurred either in British or Iranian Baluchistan or in Oman in spring.

(2) Summer swarms appeared in Sind about the beginning of May and presumably passed rapidly over Rajputana. United Provinces, Central India and Central Provinces. A large flight was observed in June in Manbhum district of Bihar. They also appeared in July in Kaira district of Gujarat.

(3) There is little information about the Punjab except that flights appeared in July and August in Dera Ghazi Khan district.

(4) Swarms appeared in large numbers in July in Marwar and began to breed but possibly owing to heavy rainfall the breeding was adversely affected. In Jaipore dead locusts are said to have impeded the passage of trains on the Rajputana-Malwa Railway.

(5) Except for one record at Kandiaro (Hyderabad district) there are no reports of autumn flights.

YEAR 1882

A. Weather Data 1882.

I—Winter-Spring Rainfall 1881-1882 (*in inches*)

1881-1882	November	December	January	February	March	April
Karachi	..	..	1·04	..	..	..
Jacobabad	..	..	0·06	..	..	..
Kalat	..	..	4·32	0·62	1·53	0·62
Quetta	..	..	2·16	1·84	1·77	1·19
D.I.Khan	..	..	0·15	0·14	0·90	2·00
Hissar	..	..	2·70	0·50	..	0·10

Apparently fairly good rainfall in January, February and March.

II—Monsoon Rainfall-1882 (*in inches*)

1882	May	June	July	August	September
Karachi	..	..	8·38	0·92	..
Umarkot	..	0·14	12·21	5·05	..
Nagar-Parkar	..	2·06	11·21	5·20	0·7
Jodhpur	0·37	0·62	5·44	3·50	0·14
Erinpura	0·65	0·20	8·40	1·60	4·9
Bikaner	1·89	0·01	6·58	2·54	2·9
Multan	..	0·35	6·68	0·69	0·1
Hissar	..	0·30	9·80	0·30	1·9

Good monsoon rainfall.

B. Locust Data 1882

I. *Winter* 1881-1882. No data.

II. *Spring* 1882. No data.

III. *Summer* 1882. No data.

IV. *Autumn* 1882. The only information on record is the appearance of locusts in October-November in the Wadhwan area of Western India States.

Summary of events in 1882

(1) Winter-Spring rainfall was favourable for spring breeding in the western areas.

(2) There is no positive information regarding summer migration in the west: it is very likely that small swarms entered Sind-Rajputana area and bred there, as there was good monsoon rainfall.

(3) The swarms reported from Wadhwan area had presumably been derived from breeding in south Marwar. Some swarms should have reached Sind in autumn, but there are no records.

The Swarmless Interval of 1883 to 1887

During the years 1883 to 1887, there were no reports of the appearance of swarms of the Desert Locust in any part of North West India. Apparently it was a swarm—free period quite comparable to the recent interval of 1933 to 1939, which was under close observation in India. It may be presumed that though swarms had disappeared the locust was present in its solitary phase form, migrating from the winter rainfall zone to the summer rainfall areas and *vice versa*, with the change of the seasons for purposes of breeding.

During part of this period, *viz.* from 1882 to 1884, however, the Bombay Locust was going through a period of mass-multiplication in its area:—composed of the Bombay Presidency proper, Gujarat, the southern parts of Central India, Berar, Western Central Provinces, Ceded districts and Hyderabad (Deccan). From 1884, however, swarms of the Bombay Locust disappeared so that during the period 1885 to 1887, India was free from all locust infestations.

CHAPTER IV

PERIOD PRIOR TO 1860

Prior to the year 1860, the information available on locusts is absolutely scanty. Whereas in Europe, reliable records of locust invasions date back to the 14th century A.D. [Waloff, 1940], very little information is available regarding locust outbreaks in India prior to the beginning of the 19th century. Records of the occurrence of locusts are often associated with the prevalence of famine and scarcity, and much of the scanty data collected on locusts in regard to the various provinces in India is found included in the paragraphs under "Famine and Scarcity" in the respective provincial Gazetteers.

So far as the incidence of the desert locust in Northern India is concerned, its invasions have been coupled with the occurrence of famines during the years 1812, 1862, 1869, 1878, 1900 and 1912. At first sight, this would seem to be somewhat of a paradox, since it is difficult to imagine how a year of famine caused by a failure of rainfall would favour locust multiplication. In all these cases, however, it should be kept in mind that famine or scarcity prevails in the year following a season of drought causing a failure of harvest, and that the famine conditions generally persist, in spite of the occurrence of favourable monsoon rainfall, till at the end of the year the new harvest becomes available for the consumption of the local population. On the other hand, locust swarms arriving from distant breeding grounds in the west can readily breed on the fall of the requisite amount of rain, and speedly become a menace to the growing crops, and can often, as they actually did in 1869, cause a prolongation of the conditions of famine or scarcity.

AVAILABLE DATA PRIOR TO 1860

The following are some of the data collected from various sources.

1746 to 1747.—The earliest available record of locust in India is from Rewa Kantha in north Gujarat in regard to the year 1746-1747, when a great famine in said to have occurred in Cutch, Palanpur, North Gujarat, Kathiawar, Rewa Kantha, Sirohi and Rajputana in general. It is mentioned that in 1746-1747, 'locusts abounded in Rewa Kantha and served as food.' The species concerned is not specified, but might have been the Desert Locust, which is not an uncommon visitant of this area.

1787 to 1796.—The next record is that of the period 1781 to 1796 in the Belgaum district of the Bombay Presidency, during which 'there was a gradual failure of crops due to continued drought and great swarms of locusts' [*Bombay Gazetteer* XXI, 1887]. Of this period, the year 1790 to 1791, was the worst and the drought would appear to have extended over a large area, inclusive of most of the districts of Bombay proper (Dharwar, Satara, Poona and Nasik), Gujarat (Ahmedabad, Surat, Baroda, etc.), Kathiawar, Palanpur and Mahikantha, and Jodhpur in Rajputana. It is not clear whether the species in question was the desert locust or the Bombay locust. The Desert Locust is said to have been recorded from Mesopotamia (Iraq), Persia and Arabia in 1796 [Olivier, 1801], and it should not be considered unlikely that its migrations had extended to India.

1799 to 1804.—The next record is that of 1803 in Cutch, where 'a scarcity, caused by locusts in that year was followed in the next season by a failure of rain.' 1803 and 1804 were years of scarcity or famine over a wide area including Punjab, Rajputana, Cutch, Gujarat and North North Bombay. It may perhaps be presumed that some of the years prior to 1803, for instance, 1799 to 1802, formed part of the invasion period of this cycle.

1809 to 1814.—The next locust cycle probably began in1809-10. According to the news items, published in the '*Asiatic Mirror*' of Calcutta on October 24th, 1810 and on November 14th, 1810, and in the '*Calcutta Morning Post*' of November 16th, 1810, it is seen that the Birbhum district of Bengal had been 'infested for several days during the first fortnight of October, 1810, with prodigious swarms of locusts, whose ravages, had, however, been confined to the destruction of the foliage and bark of trees.' On the 20th October, 1810, Barrackpore and its vicinity were said to have been visited in the afternoon by an innumerable flight of locusts, whose course was marked by the entire destruction of every kind of verdure. On the 31st October, 1810, Comillah, (Tipperah Dt.) was reported to have been visited by a vast swarm of locusts, coming from the west, which 'after demolishing some rice fields and doing much mischief among the trees (including the mango), left the place the next day (1st November) towards the hills (Hill Tipperah)'. It was said by the local inhabitants that this part of the country 'had never before been visited by these insects within the memory of man'. On the 14th November, 1810, Calcutta would appear to have had another visit by locusts, which came from the west and flew towards the north-east. The swarms were said to have afforded a 'plentiful regale' to hordes of kites, crows and adjutants. A study of the progress of recent infestations would indicate that an invasion of the Bengal area in winter should have been preceded by heavy summer breeding in Rajputana, and possibly also in the Punjab, and the subsequent eastward flights of the new generation during the autumn months.

In the year 1811, drought is said to have prevailed in Rajputana, causing a failure of crops due to the paucity of the later rains in August and September; and it would seem to have extended into the Punjab and parts of Kathiawar also. According to Captain Carnac, Resident of Baroda at that period, locusts left the territory of Marwar—devastated by drought—in the autumn of 1811 and 'reached the Pattan district (Mehsana division of Baroda State) and thence proceeded to Kathiawar'.

In the year 1812, the rains were presumably favourable for crops in Rajputana and consequently for locust multiplication; and it is said that 'in Palanpur, a promising harvest was destroyed by locusts'. In 1812-13 (presumably in the cold weather period—November 1812 to February 1813), swarms of locusts from Marwar are reported to have appeared in Gujarat as far as Broach, and also in Kathiawar and to have entirely devoured the crops. A famine is said to have been caused by locust depredations in Kathiawar—especially in Jhalawad and the northern parts of Gohilwad, as well as in Ahmedabad, Kaira and Broach. In 1813, there was a failure of rain in Kathiawar, Palanpur, Cutch, etc., followed in 1814 by damage due to excessive rainfall and the development of pestilence. In 1815, there would appear to have been a plague of rats in these areas.

From the data available, the locust infestation of this cycle may be supposed to have extended from about 1809 to 1813 in North-West India with a peak period in 1810. According to Swinton [1883], there are 'various records of locust increase along a line extending from Egypt to India during the period included between the years 1810 and 1814'.

1821 to 1826:—1824-1825 was a year of facine or scaricity in Gujarat, Kathiawar, Palanpur, Mahikantha and North Bombay, and 1825-26 was

similarly one of scarcity in South Punjab and possibly also in Rajputana. According to Cotes [1891], locusts visited Etawah in the United Provinces in 1821, and the following is an abstract of the account given by Playfair in the Trans. Med. Phys. Soc., Calcutta [1825]:—'On the 20th June, 1821, a large flight of locusts appeared at Etawah and settled in the fields and vast numbers then copulated and hovered about the place for about a month before taking their departure. On 18th July, vast swarms of young locusts emerged, and proceeded to move slowly over the country devouring the vegetation as they went. The locusts were observed up to the 31st July, by which many of them had transformed into pupae; great damage was done by them, and this, combined with the previous drought, ruined many of the cultivators. About the 31st July, flights of winged locusts were seen to pass overhead'. It is rather unlikely that summer breeding could have been confined in 1821 to Etawah only; possibly, breeding had occurred also in other south-western districts of the province, and presumably in parts of the Punjab and Rajputana, as well. In 1820, there seems to have been excessive rainfall in Kathiawar, as also in Cutch (where grain is said to have rotted); and it is probable that the infestation of 1821 had developed as one of the outcomes of the heavier rainfall of the previous year.

In 1825, there was scarcity of rain in Kathiawar, as also in Cutch and Gujarat. In 1826 it is stated that 'locusts had appeared in Jhalawad in Kathiawar and done mischief'. It may be presumed that locusts had made their appearance, as usual, in autumn from the direction of Rajputana.

1831 to 1840.—During this decade, there was scarcity or famine during the year 1833-1834 in North Bombay, Gujarat, Kathiawar, Cutch, Palanpur, Mahikantha and Rewakantha, and also in most parts of Rajputana and South Punjab. In 1837-38 there was severe famine in the United Provinces and the adjoining parts of East Rajputana, as also in Gujarat, Cutch and Kathiawar.

In 1834, ravages of locusts would appear to have augmented the ill-effects of scarcity of rain in many areas of Western India. According to *Hunter's Gazetteer,* locusts ate up all the crops in Kaira, and remissions in the revenue amounting to £ 18,655 were sanctioned, and in Ahmedabad also, where rainfall was deficient, the distress was increased by vast swarms of locusts, Cotes, [1891]. In Kathiawar, there was a failure of crops owing to want of rain and the ravages of locusts. In Cutch, 'the promise of a good harvest was destroyed by locusts, which ate up every green thing—crops, grass and leaves of trees. One flight swept through Bhuj, filling some of the houses so thickly as to put a stop to all cooking' [*Bombay Gazetteer V,* 1880]. In Rewakantha also, locusts are said to have eaten up all the crops in 1834.

Great damage by locusts is reported in the Poona district in 1835, but in the absence of any mention as to the month of occurrence, there are no clues for deciding about the species of the locust concerned, in regard to Poona, but since the Desert Locust appears to have been active at this period, it cannot be ruled out.

Specimens of the Desert Locust collected by Dussumier in 1835 off the Malabar Coast and preserved in the Paris Museum presumably belong to the Indian infestations of this period.

1841 to 1850. During this decade, the years 1841 and 1842 would appear to have been a period of scarcity in Cutch and Palanpur, and 1848 to 1849, in many parts of Rajputana.

According to Cotes [1891], Rawalpindi suffered from severe locust infestation in 1843-1844 as recorded in *Hunter's Gazetteer*:—'locusts appeared just in time to devour the whole of the autumn crop of 1843; they remained for the succeeding spring crops; and at last took their departure after utterly destroying the whole autumn crop of 1844'. This would indicate heavy and late breeding in Rajputana in the summer of 1843 and widespread spring breeding in the Punjab, followed probably by summer breeding in the Punjab and in Rajputana in 1844.

According to the *Statistical Atlas of the Bombay Presidency* [1925], locusts devoured the maize crop in the Panchmahals in 1845. With the data available, no definite statement can be made as to whether the locust under reference was *Schistocerca* or *Patanga*.

1851 to 1860.—The years 1857 and 1858 would appear to have been periods of shortage of rainfall in Cutch, Kathiawar and the Western Indian States in general. The year 1860 proved to be a period of considerable drought in Sind and most parts of North-West India.

The only record of locusts during this decade is for the Nasik district, where in 1853-1854, 'scanty rainfall is said to have occurred and much of the early harvest was eaten by locusts.' It is difficult to decide which species was concerned in this attack, though possibly it might have been the Bombay locust.

Specimens of the Desert Locust collected by Reiche in 1855 from 'Egypte and Syrie' (preserved in the Paris Museum), would, however, indicate that this species was probably in a condition of eruption at this period in the Middle East.

1861 to 1870.—From this decade onwards, fairly good information on locust infestations in India is available for study, and as already shown in an earlier chapter, the progress of the infestation can be followed year by year in correlation with meteorological data.

SECTION XI—GENERAL CONSIDERATION OF INDIAN LOCUST INFESTATIONS

CHAPTER I

SOME INFERENCES

FROM the results of the studies of locust data set forth in the foregoing chapters, it is seen that fairly detailed information regarding locust outbreaks in India is available from 1862 to 1939. *i.e.* for a period of nearly 80 years, from which certain general inferences may be made in regard to the character of the Indian infestations.

First, outbreaks of the Desert Locust in India would appear to occur in fairly defined cycles, the infestations extending over a series of years—four to six or more, followed by periods of calm during which very few swarms are to be seen. The first locust cycle for which a fair amount of continuous information is available year by year is from 1861 to 1867, of which the peak was in 1863. This was followed by a year of calm—1868, during which there was a complete failure of monsoon rainfall. In 1869, however, there was severe infestation, and the outbreak (the second cycle) continued till 1873. 1874 and 1875 were years of a break in the infestation, which was followed by a fresh locust cycle (the third cycle), that began in 1876 and continued till 1881. There were no flights in 1882, except for a few at the end of the year. From 1883 to 1887, there were no swarms of the Desert Locust in North-West India, and the next (the fourth) cycle began in July, 1888, when a few flights were reported in Sind. From 1889 to 1893, however, there was a severe outbreak which spread all over India. During the years 1894 and 1895, there was comparative calm, only a few swarms being observed in parts of northern India. The infestation strengthened again in 1896 and continued till 1898. From July, 1899 up to September, 1900 there was a break on account of a complete failure of the monsoon rains of 1899 in North-West India. From October 1900, a new (fifth) cycle started which continued till 1907. The years 1908 to 1911 formed an interval in regard to locust activity. The next cycle (the sixth) commenced in 1912 and continued till 1915, after which the outbreak subsided to a great extent though swarms were noticeable in some numbers during the years 1916 to 1919 (there being very little locust activity during 1918 on account of a failure of the monsoon). From 1920 to 1925, there was a period of comparative calm, which was followed in 1926 by the last great cycle (the seventh)—1926 to 1932, in which there was severe infestation almost all over India. The years 1933 to 1939 constituted a period of swarmless interval, during which the solitary phase was under study in the desert areas of North-West India. The year 1940 marked the beginning of a new cycle (eighth) of locust multiplication which continued till 1946.

Secondly, it is noticed that during each locust cycle, the course of infestation in India year by year presents certain common features, which are based on, and obviously closely follow, the gradual evolution of seasonal changes. During the cold weather, over-wintering swarms may be found in a partially active condition in parts of northern India, *viz.*, Punjab , Sind and Baluchistan. With the appearance of spring and the gradual rise of temperature, spring breeding may occur in the Punjab and in parts of Baluchistan in case there should be satisfactory spring rainfall. Flights of over-wintered yellow locusts may also invade Baluchistan from southern Iran and Oman during the spring months, and breed there. These flights may reach the Punjab and the North-West Frontier by April or May.

The generation *bred* in the spring months in southern Persia and Baluchistan begins to fly into India at the close of spring, the first flights reaching Sind and the Punjab during May-June. The summer flights advance rapidly eastwards over Rajputana into the United Provinces and Central India, and may reach the Central Provinces, Bihar and Bengal during June. With the development of the easterly winds of the Bay Monsoon current during June-July-August, many of the swarms would appear to be conveyed from Bihar back into the United Provinces, Punjab and Rajputana. With the fall of monsoon rains, summer breeding would appear to take place in the desert areas of Sind and Rajputana and parts of the Punjab. The new generation of locusts would usually be ready to fly by September. While some of the flights take a westerly direction towards Sind, Baluchistan and Iran, some swarms fly southwards into Gujarat and Kathiawar, and others eastwards into the United Provinces and the Central Provinces, and may reach ultimately as far east as Bihar, Bengal and Assam. In certain years, locusts may take a southerly course from Central India and the Central Provinces into Hyderabad (Deccan), Bombay or Madras. Generally, the flights that reach Bihar, Bengal, Assam, Bombay or Madras in the autumn months succumb to the attacks of birds and diseases and become ultimately disintegrated and lost, while those that fly westwards into Baluchistan and the Punjab would appear to be able to survive the winter and breed in the spring of the following year.

It is thus seen that the activities of locusts during years of infestation may be classified under (1) Over-wintering, (2) Spring flights followed by Spring breeding, (3) Summer flights, (4) Summer breeding, and (5) Autumn flights. As locust developments are almost entirely dependent on the vagaries of the weather, the seasonal activities of locusts exhibit a great deal of variation from year to year. In certain years, there may be no over-wintering and no spring breeding; in certain other years, the summer flights may not pass beyond Rajputana; and in yet others, there may be no summer breeding and no autumn flights. On the other hand, there may be two successive broods in spring or in the monsoon periods. These points will be dealt with while discussing the influence of the weather on locust economy.

Thirdly, the observations made during the recent swarmless interval of 1932 to 1939 have shown that, contrary to the usual assumption that, during such periods, locusts live a sedentary life in the desert, even individuals of *phase solitaria* are capable of making long distance migrations from winter rain areas to those of summer rainfall, and *vice-versa*, at the change of the seasons, thus bringing about the production of two broods in the year: one in spring and the other in summer. It has also been found that it is during the years of favourable rainfall that an increase of population is brought about, which in the course of further breeding under conditions of crowding in ecologically peculiar situations, may undergo a change of phase and thus cause the occurrence of incipient swarming.

CHAPTER II

A REVIEW OF LOCUST INFESTATIONS IN INDIA FROM 1861 TO 1940 IN CORRELATION WITH FLUCTUATIONS OF WEATHER CONDITIONS

1. OVER-WINTERING OF SWARMS

AS air-temperatures fall in North West India with the advance of winter, the activity of swarms gradually diminishes. Flights are confined to the warmer parts of the day, and during the long wintry nights, locusts remain resting at the base of bushes or on vegetation, often in a benumbed condition. With the rise of temperature in the forenoons, they crawl out into the open to bask in the sun, and resume activity when sufficiently warmed by the sun's rays. In no sense do locusts undergo any real hibernation—implying a state of complete winter rest and inactivity.

During cold waves or spells of cold weather, many individuals may succumb to frosts especially in upland areas, as in Sarawan, where whole swarms are known to have perished in winter in some years. During the winter months, flights are sometimes known to find their way into the valleys of the foot-hills of the Sub-Himalayas or the Sulaiman or other ranges from the open plains of the Punjab and the United Provinces, in which they apparently find shelter from the periodical icy blasts that generally follow at the heels of the western disturbances in winter.

The occurrence of over-wintering swarms in the Punjab, Sind and Baluchistan areas is one of the sequences following late or autumn breeding in Rajputana and Sind, which is itself dependent on the fall of late heavy rains in August or September. In case the monsoon withdraws before the usual time, breeding ceases early and the adults of the new generation produced in September leave the desert with the development of conditions of drought in autumn, and the greater part of the west-bound flights may pass out of India. On the other hand, in cases of late breeding, by the time the swarms of the new generation are ready for flight, winter conditions will have already set in, so that they move only tardily and linger on, in a semi-active condition, in the plains of India till February, when they pass on either into Baluchistan or into the northern districts of the Punjab.

Heavy spring infestation in the Punjab and the North-West Frontier is very often the result of the presence of over-wintering swarms in the Punjab, as the result of late breeding in the preceding autumn in the desert or in the Punjab, as had happened in the spring seasons of 1927 and 1930 during the recent cycle, and of 1863, 1873, 1890, 1891, 1901, 1903 & 1907 in the past cycles.

Outside Indian limits, over-wintering occurs, according to Predtechensky [1935], mostly in the lowland areas of southern Persia along the coasts of the Gulf of Oman and the Persian Gulf and in the Oman area of eastern Arabia, but during the winter of 1930-31 it would appear that there were no over-wintering swarms in any of these areas, and the invading flights apparently came from areas further west in Arabia.

2. SPRING FLIGHTS AND SPRING BREEDING

Spring Flights. With the appearance of warmer weather in spring, the swarms wintering in the coastal areas of British and Iranian Mekran, as

well as in Sind, Kachhi and the Punjab, become more active and take longer flights. In case of favourable spring rainfall, locusts attain sexual maturity rapidly and begin to oviposit in Mekran in February and March. This happened in 1928 and 1930, in British Mekran and according to Predtechensky [1935] also in Iranian Mekran in the Jask, Chahbar and Minab regions. After egg-laying, swarms gradually leave the area and fly northwards into the uplands of Baluchistan, where they oviposit if conditions are favourable. The progeny of these early egg-layings in Mekran, which should normally be ready to take flight by April, also fly in the same direction. On the other hand, if there should no early rainfall in Mekran, the over-wintered yellow locusts begin to move out of Mekran into the uplands of Chagai, Kharan and Sarawan earlier than usual. This happened in 1929 both in British and Iranian Mekran, and flights appeared in Seistan and Khorasan a month earlier than in 1930, as also in Chagai. In the British area, there was no rainfall even in Kharan and Chagai, so that the swarms reached the upland areas of Sarawan and Quetta-Pishin, and thence migrated into the Punjab, about three weeks earlier than in 1928.

Such early spring flights due to spring drought in lower latitudes, would appear tohave occurred in 1898, 1901, 1905, 1915 and 1923.

Spring Breeding: (1) *Baluchistan.* Usually, the flights of the yellow locust begin in the coastal areas in February-March, reach Kharan and Chagai in March-April, Sarawan, Shorawak, Quetta-Pishin and Kandahar areas by April-May, and the districts of the North-West Frontier (Dera Ismail Khan, Bannu etc.) in May-June. As these areas happen to be situated geographically, not only in progressively more northern latitudes, but also in higher altitudes, conditions favourable for egg-laying are met with later and later in spring, so that hopper infestation develops in Sarawan and Quetta-Pishin only by May-June, and in the higher ranges of Toba Achakzai and Toba Kakari (7,000 ft.) only in June-July.

(2) *Punjab.* In the Punjab, early breeding in March-April occurs only in those years in which over-wintering swarms happen to be present in the winter months and in one case—in 1891—when there were good winter rains in December-January, breeding began as early as the last week of January. Otherwise, since the flights of the yellow locust usually arrive from Baluchistan not earlier than the middle of April, spring breeding is only of limited extent in the Punjab. In 1880, when spring rainfall was in defect, swarms would appear to have concentrated and bred in the sub-montane districts of Punjab, as usually there is more rainfall in these areas.

(3) *United Provinces.* Spring breeding would appear to have occurred in the areas of the United Provinces only rarely, which should rather be regarded as a spill-over from the Punjab areas in years in which there has been heavy over-wintering in eastern Punjab and also an occurrence of good spring rainfall. From the data available, spring breeding had occurred in the Meerut district in March 1879 along the Anupshahr branch of the Ganges Canal; the next report is in the spring of 1927 in the Dehra Dun district and in the adjourning Sirmur State, and the greatest outbreak was in 1930, when breeding was spread over twelve districts.

(4) *Sind.* Spring breeding would appear to occur only rarely. It was noticed in 1890 in the north-western parts of Sind in Larkana, Kambar and Nasirabad areas and in 1930, in the Sukkur district along the borders of Khairpur State.

3. Summer Flights

As a rule, adult locusts of the new generation will be ready to take flight within two to two and a half months after egg-laying, depending on the temperatures then prevailing. The early broods produced in Mekran begin to migrate in April; those bred in Chagai, 3 to 4 weeks later; while the generation produced in the upland areas of Baluchistan and from the Khorasan areas of Persia begins to migrate only in June, or later.

The climate of the major part of Persia is of the Mediterranean type, characterised by winter rainfall and summer drought, so that these areas develop into regions of high temperatures and low humidity from May onwards. Consequently, locusts finding the conditions uncongenial to their existence would appear to flee from these areas during the summer months. At this period, Eastern Persia becomes subject to the *regime* of the dry and hot north-westerly winds, which would appear to have the effect of driving them south and south-east towards Afghanistan, Baluchistan and India.

These western summer flights begin to appear in Sind and Punjab from about the middle of April and may continue till the end of August. The earliest flights apparently belong to swarms produced in British or Iranian Mekran. Those hailing from Kharan, Chagai or Persian Baluchistan would appear during May, flights from Seistan, Afghanistan, and lower Khorasan as well as those from the uplands of British Baluchistan probably reach Sind during June; while those from more distant areas such as Upper Khorasan and Russian Turkmenistan possibly arrive only during July and August. According to Predtechensky [1935] swarms bred in central and western Persia fly south and south-west, presumably towards Arabia and Iraq.

The course of summer flights in India. The swarms that appear in Sind in May or June do not generally halt long in any place but continue their flight north-eastwards or eastwards into Rajputana, where also unless rains have already fallen and raised the percentage of humidity, they do not halt for any but short periods. In 1902, heavy rainfall occurred in Lasbela and Sind in June, and the swarms did not spread beyond Rajputana. Usually, however, May and part of June happen to be rainless periods in the desert, and flights pass rapidly eastwards into the Punjab, United Provinces or Central India. In certain years, during which there has been spring breeding in the Punjab, swarms bred locally may also begin to fly during May and are generally conveyed by the north-westerly winds that develop in the Indo-Gangetic plain at this period into the United Provinces and Central India. The strong westerly winds that usually prevail at this period in these areas may carry the swarms further east across the Central Provinces into Bihar and Bengal, as had happened in nearly twenty different years between the years 1861 and 1931. Sometimes, as the result of depressions developing over eastern Central Provinces, northerly or north-westerly winds may develop in Central India and western Central Provinces, and as a result swarms may be conveyed south or south-east into Berar, Hyderabad, Madras and Orissa, as had happened during the years 1891, 1893 and 1901.

By the first week of June, however, the Bay Monsoon makes its appearance in Bengal and Bihar and consequently easterly winds prevail at this period in these areas, which have the effect of sweeping the swarms that had reached Bihar and Bengal back towards the United Provinces and the Punjab.

4. Summer Breeding

The main conditions favouring the summer breeding of the desert locust in nature are: (1) the occurrence of soaking rains which would provide the requisite conditions of soil temperature and moisture for the development of eggs, and (2) the presence of sandy or loamy soils ensuring soil drainage. Very heavy rainfall would be prejudicial to the development of eggs laid, as it would lead to conditions of water-logging even in light soils. The heavier rainfall of Bihar and Bengal and of eastern United Provinces and of the sub-montane districts of the United Provinces and the Punjab is thus not favourable for egg-laying, and the main areas where oviposition takes place are (1) Rajputana (especially the desert areas of Western Rajputana), (2) the desert areas of Sind, (3) the eastern and the south-eastern districts of the Punjab (Karnal, Rohtak, Gurgaon, Ferozepore etc.) and (4) parts of the Western India States. In years of good summer rainfall, oviposition may also occur in the eastern parts of Baluchistan, such as Lasbela, Kachhi, Sibi and Loralai. The main area of breeding in most years is, however, the Rajputana desert, in the sandy wastes of which the desert locust finds ideal conditions for egg-laying and multiplication, whenever a requisite amount of rain has fallen.

The time of rainfall is also very important in respect of locust breeding. Good rainfall in June and July would result in an early development of swarms, which may lead to the development of a second summer generation, if further good rain should happen to fall in August or September. On the other hand, a long break in August would bar further breeding, even if there should be the requiste amount of precipitation in September. Heavy rainfall in August or September would generally result in the development of late breeding and consequently lead to a considerable over-wintering of swarms in the Punjab, United Provinces and Sind.

Rajputana. Although Rajputana is by far the most important area of summer breeding in north India, only scanty information is available in regard to the actual areas of oviposition in this vast area, for years prior to 1930. However, as generally egg-laying is dependent on local rainfall, clues furnished by the distribution on rainfall in the different parts of the desert have been made use of in these studies, in cases where such rainfall data have been available. In general, breeding would appear to be confined to the region of western Rajputana, including the Shekhawati sector of Jaipur and the Ajmer-Merwara areas. The states of eastern Rajputana would appear to be usually less infested except in years of unusually heavy multiplication.

Sind. In most years, hopper infestation is confined to the desert areas of Thar-Parkar district, but in some years, as in 1913 & 1929, breeding may occur in the sub-montane areas of Larkana and Dadu districts along the base of the western foot-hills. In 1929, however, there was extra-ordinarily heavy breeding in Sind, the infestation being spread over almost all the districts of the province—in alluvial as well as in desert areas. In the Thar desert areas, breeding generally starts on the fall of good monsoon rains, the ovipositing swarms almost invariably coming from the east from Marwar areas.

Punjab. Swarms usually reach the Punjab from the western areas in June and become mixed up with the local spring-bred locusts. In the course of the month, swarms may fly eastwards into the United Provinces and Central India, but with the beginning of the monsoon rains, in July, the flights would appear to be brought back from the

United Provinces by easterly currents from the Bay to eastern Punjab Oviposition occurs first in the south-eastern districts of Hissar Rohtak and Gurgaon, and subsequently with the extension of the monsoon further west, also in the central and northern districts. It is, however, only rarely that the whole province is over-run by hopper infestation; during the 1926—31 cycle, such extensive summer breeding occurred in 1929 and 1930, and in the past cycles during the years 1863, 1891, 1897 and 1906.

United Provinces. Although the province is visited quite frequently by locust swarms, occurrence of breeding is rather uncommon. In the past, summer breeding took place in Etawah in June-July, 1821, (Cotes, 1891) and after over a century, again in the years 1929, 1930 and 1931. The infestation in 1929 and 1930 was on an unprecedentedly large scale and affected nearly 18 districts. It is rather difficult to say why locust breeding, which is known to occur fairly frequently in Gurgaon and Rohtak should not extend across the Jumna River into the adjoining districts of the United Provinces. Possibly light infestations might not have been noticed or reported in the past. It is also likely that the easterly winds may, in most years, sweep the flights out of the United Provinces before eggs could be laid.

Western India States. Swarms reaching Kathiawar and north Gujarat in June, may, sometimes, lay eggs under favourable conditions of rainfall. This had apparently occurred in the years 1879, 1889, 1897 and 1914.

Baluchistan. In years when the monsoon happens to extend into Baluchistan, breeding may take place in Lasbela, Kachhi, Sibi and Loralai, and in some years also in Jhalawan and Mekran. In 1914, when heavy rainfall occurred in June in Mekran, breeding took place in the Dasht valley; and under similar conditions in July-August, 1930 in Kulanch.

Late Summer Breeding. As already stated, late breeding follows heavy rainfall in August and September. It is known to have occurred in 1879 in Thar, Rajputana and the Punjab, in 1878 in the Punjab and the Western India States, in 1889 in Rajputana, in 1891 in the Punjab, in 1900 & 1902 in Thar and Rajputana, in 1905 in Marwar, in 1906 in the Punjab, in 1913 in Kachhi and North Sind, in 1926 in Thar and Marwar and in 1927 & 1929 in Sind.

5. Autumn Flights

With the withdrawal of the monsoon from North-west India in September, (*vide* Plates 54-55) the areas of Sind and Rajputana and southern Punjab become regions of comparatively low humidity and high temperatures. As the moisture-laden monsoon winds cease to blow, the air becomes dry, the sandy soils give up their moisture and the vegetation begins to dry up, so that locusts find the conditions of desiccation too trying for their existence and begin to leave the area by flight. The direction of their migration would naturally depend on the wind movements prevalent at the time. An examination of the wind charts for September and October (*vide* Climatological Atlas of India) would indicate that in the north-eastern parts of Rajputana the winds are north-westerly, while in the eastern parts they range from north-westerly to westerly, so that the direction of flight of swarms from these areas would naturally be eastwards or south-eastwards. In the southern parts, the winds are generally northerly in autumn and the flights are usually directed towards Cutch, Kathiawar and north Gujarat. Winds in the south-western areas are generally easterly or north-easterly, while in the

north-western parts (Bikaner and Jaisalmer) they may vary from south-easterly to easterly, so that flights from western Rajputana have usually a western trend. At times, especially in the rear of western disturbances, strong north-easterly winds may be noticeable in the greater part of the desert areas.

These notes would indicate, in general, that swarms originating in the eastern parts of Rajputana, including eastern Bikaner, would take an easterly direction, and those produced in south Marwar and Sirohi would leave south-wards, while the flights from Thar, Mallani, western Marwar, Western Bikaner and Jaisalmer would be in a westerly direction. In the Punjab, swarms produced in the north-eastern and eastern districts would appear to be carried south-eastwards into the United Provinces, Central India and Central Provinces, while those from the western districts take a westerly direction. In 1930, when there was no late breeding, very few swarms took a westerly direction, whereas in 1931, it was noticed that even swarms produced in Ajmer and other parts of eastern Rajputana and south-east Punjab, were swept westwards by an unusual development of easterly winds in September and October.

(a) *West-bound Flights.* Westward flights, are, in most years of infestation, a general feature of the annual cycle of events, but in the following years, there was an almost total *absence* of west-bound flights:—1873, 1893, 1894, 1895, 1915, 1928 and 1930. In years of early breeding, westward movements cease early and may not be seen after October, whereas whenever late breeding occurs, flights may extend into the winter months and may continue even up to the middle of April.

(b) *East-bound Flights.* Whenever extensive breeding has occurred in Rajputana and the Punjab during summer, east-bound flights usually take place. While in years in which the breeding is somewhat limited, the flights may not go beyond the United Provinces, Central India or the Central Provinces, in years of heavy multiplication, they may reach as far east as Bihar, Orissa and Bengal, and may sometimes even extend into Assam, as had happened in 1863, 1878, 1890, 1896, 1897, 1906 and 1930. In these cases, normal development of westerly winds in October and November would appear to have been mainly instrumental in carrying the swarms so far east.

(c) *Southerly Flights into Madras.* In certain years, swarms reaching Central India would appear to have turned south into the western parts of the Central Provinces and Berar, and thence had been carried further south into Hyderabad State and north Madras or south-west into the Bombay area. In 1878, flights reached as far south as Dharwar in Bombay, and Bellary, Kistna and Nellore in Madras; and in 1889 again they visited Bellary, Godavari, Kistna and Vizagapatam in Madras Presidency. In the following year (1890), swarms proceeded as far as Dharwar in Bombay and crossed into Mysore and in Madras they invaded the Ceded Districts and flew southwards into Chittoor and Chingleput, reaching as far south as Tiruvallore only a few miles from Madras City. In later years, however, though swarms reached as far as Nasik and Thana more than once, they would appear not to have penetrated further south till recently in 1941 when swarms reached the Bellary District in Madras, (though in 1930 they reached as far as Warangal in Hyderabad).

In most of these years, it is observable that these southerly flights had been caused by the development of northerly or north-westerly winds in September or October in the areas of Central India and Central Provinces in connection with the formation of storms on the Orissa coast.

(d) *Southerly Flights into Gujarat.* As a general rule, swarms produced in south Marwar, Thar-Parkar and Sirohi fly southwards in autumn into Cutch, Palanpur, Radhanpur and other States of Western India, and into north Gujarat and Kathiawar. Some of these flights may often pass further south into Broach, Baroda and Surat. The swarms may sometimes remain active in these areas till January or February, but sooner or later they eventually disappear. Possibly many may fall a prey to birds, but those that survive would appear to pass gradually westwards into Sind and Baluchistan during the spring months.

Flights over the Sea. There are numerous records of captures of individuals of the desert locust on board steamers passing through the Red Sea. On several occasions it has been reported that steamers had to plough through masses of dead locusts. A similar phenomenon was recorded in October 1932 by a steamer passing off the coast of Mauretania [Uvarov, 1933]. In fact, on the West Coast of Africa, migration flights of the Desert Locust are said to have reached not only the Canaries, and the Madeira, but as far as Azores—over a thousand miles from the nearest land, [Uvarov, 1933]. Indeed, according to Waloff, "in August, 1869, great numbers of *Schistocerca gregaria* Frosk., coming from the African continent, appeared in England all along the cost of Devon and Cornwall, from Plymouth to Penzance," (Waloff, 1940).

There is no doubt that locust flights often find their doom in the sea. According to the *Bombay Gazetter, V. Cutch* (pp. 173-6), it was reported that in October, 1862 there was a heavy locust visitation in Cutch, which apparently came from the north and east, and that "after devastating crops, it would seem to have been driven west and into sea. Captains of ships from Muscat and Zanzibar are said to have found the sea covered with dead locusts about a hundred miles from Mandvi." Apparently the swarms had been swept into the sea by strong currents of wind accompanying a storm. Doubtless, large numbers of locusts perish in the sea, whenever flights pass over large arms of the sea, such as the Gulf of Oman and the Persian Gulf. In November-December, 1929 when large flights from the direction of Sind passed over Mekran westwards, it is known that masses of the carcasses of locusts were thrown up on the beaches all along the Mekran Coast.

In 1930, north-easterly winds that were observed in Bombay areas from 7, October are known to have carried swarms from the Berar side into Nasik, Thana and Kolaba districts. The find of a specimen of the pink form of the desert locust by Mr. T. Bainbrigge Fletcher (then Imperial Entomologist, Pusa), on the 13 October, 1930 on board a P. & O. ship bound for Colombo about 9°N.Lat., about 250 miles off the Laccadives, is of particular interest. This would indicate that some of the swarms reaching the Konkan Coast about 7, October, 1930 had been blown out into the sea, and that the specimen in question had survived a flight of nearly 800 miles from the Konkan Coast.

Flights over the Himalayan Snows. Mountaineers have often found, according to KIM. (*"Statesman"*—Calcutta), great red patches on snow peaks on the Himalayas, which have proved to be masses of dead locusts that had perished on the snows. Sir Olaf Caroe found in September 1915, masses of dead pink locusts on the Pindari Glacier (13,000 feet) in Kumaon. Possibly, such cases of locust flights "committing mass suicide on the snows" are not merely isolated instances, but form probably a phenomenon of fairly common occurrence in years of heavy locust flights. Swarms flying in hilly areas are presumably helpless when high winds carry them up the valleys on a bright sunny day and deposit them on a great snow field or on a glacier.

Myriads of locusts perish in this manner on the snows, and probably, as in the case of masses of locusts blown off the land into the sea, this is one of the ways by which over-multiplication of the insect world is controlled in nature.

The Role of Winds in the Movements of Locust Swarms

In the course of the foregoing studies of locust movements in correlation with meteorological data, there has been abundant evidence of the positive influence of winds, in general, on the direction of swarm flights. In many cases, the anomalies in the distribution of swarms in particular years have been found to be due to the peculiarities in the development of the weather of those years. In Plates 49 & 50, the general agreement of the directions of wind and swarm movements on particular dates is well seen. In Plate 49, which pertains to the locust movements during the last ten days of May, 1930, the general trend of locust flights is seen to be from west to east, and is in correspondence with the direction of the westerly winds then prevalent. In the case of Pl. 50, which relates to the situation in the first fortnight of July, 1930, the general trend of flights is from east to west which is in accord with the easterly direction of the monsoon winds. Text-Fig. 24 is a copy of the weather chart of the India Meteorological Department for 23rd September, 1930, and shows the development of northerly to north-westerly winds in the regions of the Central Provinces, Bombay, Hyderabad and Madras under the influence of a depression forming on the Orissa Coast. The disposition of winds on this and the following days was apparently favourable for the transference of swarms from the direction of Central Provinces into Bombay and Hyderabad (Warangal, 29th October 1930). There are numerous similar other instances in which the consonance between the directions of locust and wind movements have been observable.

In fact, though in the body of the reports of locust flights recorded in India during the past years, there is usually no reference to the direction of the winds prevalent at the time, there are a few instances in which the accord between the wind direction and the locust flight has been indicated. For instance, the Naib Wazir, Mekran reported on the 16th August 1931: "Locusts appeared at Turbat from the south-eastern side and owing to the strong wind they were carried away to the north-western direction." In a report dated 11th October, 1931, the Mukhtiarkar, Shahbunder reported: "Locusts in great swarms appeared today from north-east and are passing to south-west. The north-east wind has blown since two days and appears to have brought them." Predtechensky [1935] observes as follows, in regard to locust movements in Persian Mekran in 1930: "Usually the flights towards the north and west coincided with the south-east winds, flights from the north and west with the north winds." In regard to locust flights in Arabistan in 1931 he states: "On 1/iv, the flights from the Basrah region changed towards the south in the direction of the Shatt-al-Arab delta, evidently under the influence of the north-west wind, which was blowing fairly strongly." In general Predtechensky agrees that "the influence of wind on migratory swarms cannot be denied, though it can hardly be a significant factor in inducing locusts to fly and occupy particular localities without reference to the temperature conditions."

Temperature is, of course, a factor, the influence of which should always be taken into consideration in studying locust movements. In summer and autumn, however, the prevailing temperatures in India are rarely unfavourable for flight, so that there is generally no clash between the directions of wind movements and locust flights. Under the temperature conditions prevalent in winter and early spring, however, the

situation is different. In winter it is only if the air currents are characterised by a fair degree of warmth that locusts show any response to changes in wind movements. If the winds in question are chill blasts that blow in the rear of western disturbances, locusts do not evince any activity, but get into cover, while they continue. In the regions of Sind and the Punjab, westward migration of swarms is noticeable only during October and November, during which period the north-east winds continue to be, on the whole, a warm air current. It is only with the onset of winter that the north-easterly wind changes into the chill dry wind, which locusts dislike. During the winter months, the weather is liable to much variation, as western disturbances pass over the country, they are preceded by short spells of warm moist winds followed by showers. and succeeded by chill blasts of the north-east wind in their rear. Locust movements, therefore, occur only during the warm front stage of such cold weather depressions, in which the winds are westerly or southerly. The movements of locusts in spring in the Mekran areas in the direction of north or north-east are presumably activated by wind currents of the "warm front" stage of winter depressions.

In Egypt, Mackillop and Gough had observed, on 17 separate occasions, during the invasion of 1915, that the arrival of flying swarms coincided with barometric depressions, [Uvarov, 1931], but according to Ballard [1932], Egypt becomes liable to the danger of invasion of locusts. not when the depression is actually over it, but at the time when it is about to approach the country. Ballard is, moreover, definitely of opinion that "the bulk of the locust movements from Egypt to the Sudan and *vice versa*, are controlled by winds." [Ballard *et al.*, 1932].

Discussing the data collected in East Africa on the direction of movements of swarms with reference to wind directions, Waloff [1946] observed as follows: "It will be seen that the best correspondence of the direction flight with wind obtains when the weather is dry, the monsoonal currents well developed, and the swarms are immature. During the transitional periods both the winds and the directions of flight become more variable, though the general transitions from the northerly to the southerly and *vice-versa* are reflected in the reversals to the direction of flight. During the rains, which fall in the transitional periods, the absence of the clear-cut trend is accompanied by the reduction in flying activity and by breeding. Finally there is some evidence to suggest that during the final stage of their life-cycle, just before they die off, old mature swarms tend to move against the wind." However, in regard to the last observation, Waloff observes, "that this discussion is not based on comparison of movements with the winds that blew on every occasion, but with the prevailing winds....." and adds "only comparison of the individual flights with the exact conditions under which they take place can throw more light on the question, and in such comparisons the physiological state of the locusts themselves must always be borne in mind".

CHAPTER III

SYNCHRONEITY OF EXTRA-INDIAN INFESTATIONS WITH THE INDIAN CYCLES

EXCEPT in the case of the more recent cycles, not much information has been available to the writer in regard to any contemporaneous outbreaks of the desert locust outside India, whether in Iran, Iraq and Arabia, or in Egypt, Algeria and Morocco. Some information on locust out-breaks in the past in the African area is found in the paper (Annexe 11) submitted by the Portuguese delegation to the IV International Locust Conference at Cairo [1936], and in Pasquier's paper on "Prevision et Periodicite des Invasions de la Sauterelle Pelerine en Afrique du Nord", 1942, and a few data are available also in Swinton's paper on "Locust Migrations and Sunpots" (1883). The writer is indebted to Dr. B. P. Uvarov for some information on locust invasions in the last century in Iran, Iraq, Egypt and India, and to Dr. M. L. Chopard of Paris Museum for allowing him to take notes in respect of certain specimens of the Desert Locust in the National Museum of Natural History, Paris, collected from various places in the east during the 19th century. Further information has been found in respect of the occurrence of swarms in the Atlantic area in Waloff's papers [1940 & 1946] on the migrations of locust swarms.

TABLE

THE SYNCHRONEITY OF EXTRA-INDIAN INFESTATIONS WITH THE INDIAN CYCLES

(Prepared from the data available)

Period	Indo-Iran Region		Arabia-Sudan Region						West African Region			
Period	India	Iran	Iraq	Arabia	Red Sea	Palestine & Syria	Egypt	Sudan	Kenya	Algeria	Morocco	Atlantic Region
1401-1500												1496 Teneriffe
1601-1700												Spain 1618 1619.
1701-							1716					
1790				1762	1762					1762		
1796-1804	1803	1796	1796	1796						1799	1799	
1809-1815	1810-1814	1810-1814					1810-1814					1811 Canaries
1821-1830	1821-1826											
1831-1840	1834-1835			1839 Jidda								1839 off Mauretania
1840-1850	1843-1845									1845		1841 Canaries
1850-1860	1853-1855					1855	1851 1855			1856		1844 Madeira
1861-1867	1862-1863					1865-1866				1864-1866		1864 (England); 1865 (Mid Atlantic).
1869-1873	1869-1873	1869		1869						1869		1869 (England).

Period	Indo-Iran Region		Arabia-Sudan Region						West African Region			
Period	India	Iran	Iraq	Arabia	Red Sea	Palestine & Syria	Egypt	Sudan	Kenya	Algeria	Morocco	Atlantic Region
1876-1882	1876-1882					1878						
1888-1900	1888-1895	1889-1890			1889-1890	1890-1892						
	1896 1898	1897-1899				1899						
1901-1910	1900-1907	1901-1908				1902-1904	1903-1904		1901 1909			
1911-1919	1912-1919	1913-1916			1919	1914-1915	1914-1915	1912-1916				1916 (Mid Atlantic) Mauretania
1920 1925	1922-1924	1923										
1926 1934	1926-1932	1927-1932	1928-1932	1926-1932	1925-1931	1928-1930	1928-1931	1926-1932	1928-1930	1926-1934	1926-1934	1931-38 Canaries
1935-1941	1935-1940	1941			1933-1936		1936-1937			1939		

From the data tabulated in the table on pre-page, it is seen that the information on hand for the earlier years is very scanty indeed. The invasion of Teneriffe (presumably from West Coast of Africa) in 1496, and of Spain (possibly from Morocco) in 1618-19 indicate the probable occurrence of severe outbreaks at that time in Africa. In the 18th century, Forskal collected specimens of the Desert Locust in Egypt in 1716 and named it "*Gryllus gregarius*". There was an invasion again in 1762, when it was also met with in Libya, in Nubia and in "the Arabian Gulf" (presumably the Red Sea). Towards the end of the century, the Desert Locust was present, according to Olivier [1801], in Mesopotamia, Iran and Arabia in 1796. According to Jackson, [Port. Deleg. 1936], there was an invasion in North Africa, in 1799, from the south from the direction of the desert, and enormous numbers of locusts were drowned in the ocean owing to the action of a violent wind. As there is record of a locust invasion in Cutch in India in 1803, the period between 1796 and 1803 may perhaps be considered as a single cycle, during which locust activity was spread over all the regions of habitat of the desert locust.

According to Swinton [1883], there were "records of locust increase along a line extending from Egypt to India during the period 1810 to 1814." In India, there was widespread infestation in 1810, 1811 and 1812. According to Waloff [1946], a locust swarm was observed 200 miles off the Canaries on 21st November 1811.

During the decade 1821 to 1830, there was infestation in the United Provinces in 1821 and in Kathiawar in 1826, but there is no information for other areas. During the next decade, 1831 to 1840, there was severe damage to crops in Western India in 1834 by locust swarms, and in 1835 in Poona. There are no data for the extra-Indian areas, except for the circumstance that specimens of pink locusts collected at Jidda in Arabia in 1839, are preserved in the Paris Museum and that it is known that large swarms were met with at sea 50 miles off the coast of Mauretanio on 13th September 1839 [Waloff, 1940].

During the next decade, 1841 to 1850, there was severe infestation in 1843-44 in the Punjab and flights occurred in Panchmahals in 1845. In the African area, locusts invaded the Canaries in 1841, the Madeira Island In 1844, and Algeria in 1845.

During the decade, 1851 to 1860, there is no infestation on record, except for a report of locust damage in Nasik in 1853-54, which might have been that of *Patanga*. In 1851 there was probably an outbreak in Egypt, and specimens collected by Reiche from "Egypte & Syrie" in 1855 occur in the Paris Museum. According to Pasquier [1942], 1856 was the year beginning a new cycle in North Africa.

Fairly continuous information in regard to the Indian infestations is available from the year 1861. During the cycle, 1861-67, there was a severe outbreak in North-west India in 1862-63, and according to Swinton [1883], "an erratic flock came in the autumn of 1864 to the coast of Cornwall in England" from Algeria, and a swarm was met with in Mid-Atlantic 1200 miles off Mauretania in November 1865, [Waloff, 1940].

During the next cycle, 1869-1873, there was infestation in Persia, Arabia and Algeria. In August, 1869 great numbers of desert locusts coming from the African continent, reached the south coast of Devon and Cornwall and spread into the interior of England as far north as Nottinghamshire, and even reached the southern coast of Ireland in county Waterford, [Waloff, 1940].

During 1876—1882, there was infestation in Algeria and Morocco in 1876—1878; and in Palestine in 1878. During the cycle, 1888 to 1899, there was wide-spread attack from 1889 to 1892 in Iran, Palestine, the Red Sea areas, and Sudan. There was an outbreak in Kenya in 1892-94, and in Algeria and Morocco in 1890-93. There was also infestation in 1896-1898 in India, in 1897-1899 in Iran, in 1899 in Palestine, and in 1898 in Kenya.

During the next cycle, 1901-1908, there were outbreaks in Iran during 1901-1903, in Palestine in 1902-1904, and again in 1908, in Egypt in 1903-1904, in Kenya in 1901-1909, and in Algeria in 1905.

During the next period, 1911-1919, there was infestation in Iran from 1913 to 1916, in Palestine and Egypt in 1914-1915, in Sudan in 1912-1915, and also in 1919, and in Algeria from 1913 onwards. Numerous specimens of locusts came aboard a ship at Sea about 1200 miles off west Africa on 7th October 1916 [Waloff, 1946].

During the swarmless interval of 1920 to 1925 in India, there were light infestations in India (Mekran and Kachhi) in 1922, 1923, and 1924, and a few swarms in Iran in 1923. There was presumably a calm in other areas.

During the last great cycle—1926 to 1934, there was an outbreak in India from 1926 to 1932, from 1927 to 1932 in Iran, from 1928 to 1932 in Iraq, from 1925 to 1931 on the Red Sea areas, from 1926 to 1932 in Sudan, in 1928 to 1930 in Palestine and Egypt and in Kenya, and from 1926 to 1934 in Algeria and Morocco. Swarms reached the Canary Islands in 1931 and 1932, and the Madeira and the Azores in 1932.

During the interval of 1933 to 1939, there was a light incursion in India in 1935, and activity in the outbreak areas of the Red Sea in 1933-34, and an infestation in the Western Desert in Egypt in 1936-37. The recent locust cycle (1940-46) began in India in 1940, in 1939 in the Morocco-Nigerian area [Pasquier 1942], and in 1941 in Iran.

From the data tabulated above, it is obvious that locust outbreaks, whenever they occur, would appear to become observable more or less simultaneously in almost all the different regions of the wide area of habitat of the locust extending from western Africa to northern India. When there is a decline, the fall in the infestation is noticeable sooner

or later all over its habitat. This is probably due to the fact that its habitat is made up of a complex of winter-rain and summer-rain breeding grounds spread over a wide area of desert or semi-desert regions, and any changes in the climatic conditions in these would apparently be felt sooner or later all over the area.

Studies of the movements of swarms in the Eastern African area by Waloff [1946] have brought evidence in respect of the existence of an Inter-change of flights between East Africa, Anglo-Egyptian Sudan and S. W. Arabia, which has a considerable influence on the course of an outbreak. Similarly, Donnelly [1947] has shown in his studies of the migrations of the Desert Locust in Western and N. W. Africa that there is a certain amount of inter-change of swarms between Anglo-Egyptian Sudan and French Sudan through Tchad Territory in the course of the year. As such an inter-relationship of flights during an outbreak is likely to be reflected in a similar exchange of *solitaria* populations when swarms are non-existent, the out-break centres scattered over the vast area of locust habitat are doubtless, connected with one another by a periodical exchange of populations, so that incipient swarming produced in one of the centres would sooner or later make its influence felt all over the area. It is probable that the Red Sea areas, being centrally situated, are probably more important than the rest in respect of the starting of a fresh cycle of infestation. There is some ground, therefore, for considering that the origin of the recent cycle of infestation (1940-1946) in India had probably been linked up with the small out-breaks that had been noticed on the Red Sea and Egyptian areas between the years 1933 and 1938.

CHAPTER IV

ORIGIN, PROGRESS AND DECLINE OF LOCUST INFESTATIONS IN INDIA

1. THE NATURE OF INDIAN INFESTATIONS

IN former days, the prevailing idea of locust infestations in India was that, once swarms entered India from the west, they continued to remain and breed in India until the outbreak came to an end by the incidence of disease, or action of natural enemies, or as a result of failure of rainfall. In regard to the outbreak of 1843-44 in the Punjab, the following statement occurs in Hunter's Gazetteer: "Locusts appeared just in time to devour the autumn crop of 1843, remained for the succeeding spring crops and at last took their departure after utterly destroying the autumn crops of 1844." The results of the studies of recent infestations have shown that locust populations—whether of *solitaria* individuals or of swarms of *gregaria*—are rarely stationary, but migrate at the change of the seasons. Swarms bred in spring in the Punjab would generally fly south-east into the United Provinces or Central India, though, in their place, other flights from the west might be expected to enter the province in May or June. The swarms reported attacking the autumn crops in the Punjab might really have been derived from the summer broods produced in Rajputana, so that the statement made above can hardly be taken at its face value.

As already stated in an earlier chapter, an analysis of the events of any particular year of locust infestation in India would show that they consist, essentially, of spring breeding in winter rainfall areas, of summer breeding in summer rain areas and of flights from the spring-brood areas to the summer-brood areas at the end of spring and *vice versa*, at the end of summer.

1. *Spring breeding*. This would take place in Baluchistan or Punjab, in the contingency of (a) the presence of local over-wintered swarms, or (b) the occurrence of spring flights of the yellow locust from southern Iran, and (c) the fall of favourable spring rains.

2. *Summer flights*. Swarms bred in the Punjab would fly, jointly with those bred in Baluchistan or in Iran coming through Sind and the Punjab from May onwards, eastwards into the United Provinces and Central India, and reach as far as Bihar or Bengal by end of June. The easterly winds of the Bay Monsoon in July would, however, convey most of them back into the Punjab or Rajputana.

3. *Summer breeding*. This would occur mostly in Sind, Rajputana and the Punjab, if there is satisfactory rainfall; as also late breeding, should ample rainfall occur in August or September.

4. *Autumn flights*. Swarms bred in summer would begin to fly in September, partly in a westerly direction towards Baluchistan, partly eastwards into the United Provinces, Central Provinces, Bihar and Bengal, or southwards into Bombay and Madras areas or into Western India, Cutch and Kathiawar.

5. *Over-wintering*. This can occur within Indian limits only if there is late breeding. As to the autumn flights, those that reach the eastern or southern parts of India are never known to breed there. Probably most of them become disintegrated as a result of attack by birds and become scattered. On the other hand, the west-bound flights would appear to reach Baluchistan and Iran and breed there in the spring months, while the belated swarms belonging to the late summer or autumn brood

apparently linger on in India during winter and breed, in case of satisfactory spring rainfall, in the Punjab or in parts of Baluchistan. In studying the conditions affecting the origin, progress and decline of Indian outbreaks, it should, therefore, be kept in mind that it is only the swarms that reach western Punjab or Baluchistan late in the year and breed there in spring, that form the direct links between the infestations of successive years.

2. Locust infestation cycles in India: their Origin, Progress & Decline

As mentioned earlier, it is only since 1861 that the necessary amount of information on locust incidence needed for delimiting the length of each cycle and for studying its developments year by year, has been obtainable. Taking the period 1861-1867 to be the first cycle of the series, one finds that there have been seven cycles up to 1932:—1861-67 (7 years), 1869-73 (5 years), 1876-1881 (6 years), 1889-1898 (10 years), 1900-1907 (8 years), 1912-1919 (8 years), and 1926-1932 (7 years). The duration of each locust cycle has thus ranged from 5 to 10 years, while the intervals without locusts have varied from 1 to 8 years.

Origin of Cycles. The ultimate origin of a new cycle of infestation is bound to be traceable to the formation of outbreak centres, where under favourable ecological conditions the solitary phase locusts undergo a change of phase and give rise to incipient swarms. As these outbreak centres are generally found distributed over a wide area and are not likely to attract the attention of any but trained people, it is natural that there should have been a lack of exact information relating to the beginnings of the initial outbreaks prior to 1931, since which time observations on the solitary phase by specially trained staff were begun in North-western India, as also about the same time in the African areas.

In the case of the years 1869, 1876 and 1889, the new cycles were apparently ushered in by the sudden entry in the regions of Sind and Punjab of large swarms, which straight away laid eggs and bred in the Punjab and in the Sind-Rajputana desert areas. As, however, very little is known about the antecedents of these swarms, no statement can be made as to whether they were derived from outbreak centres in Baluchistan, Iran or Arabia, or from gregarious breeding in eastern Arabia started by flights coming from further west. In 1888, however, satisfactory rainfall is known to have occurred in the western areas in spring, and since a few swarms are recorded as having been active in July in Sind, incipient swarming had no doubt started in the spring of that year, so that 1888 should, in fact, be taken to be the first year of this cycle.

In the case of the years 1869, 1876 and 1889, the new cycles were occurrence of swarm flight was in August-September from the Sind Rajputana area and it should, therefore, be presumed that the desert areas had functioned as the primary outbreak centres in these years. As a rule, however, the desert areas are covered, in normal years, so densely with vegetation after rainfall, that conditions are unfavourable for bringing about crowded breeding, and in fact, often swarms of fliers or hopper bands have a tendency to revert to the *solitaria* condition when they get scattered among the vegetation. In the case of these three years, however, droughts of considerable magnitude had occurred in the preceding season: (1889, 1911 and 1939) in the Sind-Rajputana desert, and it is surmised that the vegetation in the desert areas had assumed a patchy character during the rains, which had the effect of causing the locust migrants to concentrate on such vegetation islands and bring about crowded breeding. Evidently such patches had functioned as a series of outbreak centres.

As to the character of the breeding in such centres, it is not possible to say whether an actual transformation of phase from *solitaria* to *transiens or gregaria* was concerned or only a crowded breeding of mixed groups of forms of the different phases. From the observations made in Mekran, Sind and Rajputana in 1935, [Rao, 1936], it is seen that, at the time of the summer flights, locusts might at times appear not in the form of large swarms, but as an incursion of large numbers of isolated fliers (mostly *transiens* or *gregaria* in phase), or in the form of loose thin groups of such individuals, which would be able to breed in the desert in the event of satisfactory rainfall. Observations made by the Locust Warning Organization in June and July, 1940 showed that a similar incursion of *transiens* and *gregaria* individuals had occurred that year, and it is not unlikely that such an immigration of locusts from the west had also taken place in 1912. In the case of 1900 too, swarms are known to have entered Chagai and Sarawan in Baluchistan from Iran or Afghanistan and attacked crops in summer, though there is no record of their entry into Sind and Rajputana. In all these three cases, the groups of individuals bringing about crowded breeding were probably derived in great part from outbreak centres in eastern Arabia or southern Iran, and perhaps partly included contingents from remnants of swarms coming from regions further west.

In the case of the year 1926, it is definitely known that outbreak centres had developed in parts of British Mekran, but there is reason to believe that a good part of the immigrant locust population that started the infestation was derived from outbreak centres or perhaps from areas of *gregaria* breeding situated beyond the limits of India and in fact, in the later stages of the outbreak in Sind, the invasion had actually taken place in the form of swarms of small or moderate size.

As to the case of spring breeding that occurred in the Dasht Valley of Mekran in April-May, 1923, it should probably be taken to be an instance of *gregaria* breeding rather than as an outbreak centre, for, it would look as if the migrants that had appeared at that time and bred on the wet soils of the high-flood terraces of the Dasht River, were really locusts of the *gregaria* phase that had been impelled to leave the western areas, by reason of the spring drought that prevailed there, and had entered Mekran either in the form of solitary individuals, or of thin swarms, and laid eggs.

Progress and Development of the Indian Cycles. The size and extent of infestation in any year is dependent on the extent of breeding in spring and in summer. With extensive and heavy breeding in the winter-rain areas, the size of the summer flights is bound to be definitely large. During the years 1891, 1897, 1901 and 1915, spring breeding was wide spread both in the Indian and the extra-Indian areas and the swarms that invaded India in summer were extremely numerous. A great many reached as far as Assam in these years, and during 1891 and 1901, some of the flights spread south as far as Madras by June.

If heavy breeding occurs in summer, the autumn flights are bound to be similarly large, and may reach eastwards as far as Bengal and Assam and south as far as Madras and Bombay. However, the flights that move in autumn towards the east and the south do not count in respect of the building up of the succeeding year's infestation, and should, therefore, be reckoned as lost swarms. On the other hand, the swarms that fly west would join hands with those overwintering in the winter-rain areas of Iran and Arabia, and function in the production of a new generation in the following spring.

Decline of Outbreaks: Cycle of 1926-1932. During the last cycle, westward migration occurred in the autumn months of 1926 and 1927, and the swarms that reached beyond the borders had apparently taken some part in the production of the flights that invaded India in summer in 1927 and 1928 respectively. In 1928, however, there was comparatively little of summer breeding owing to a defective monsoon, and only a few swarms were noted entering Sind and Baluchistan early in the autumn, but none in November and December, and there were no eastward flights too. According to Predtechensky [1935], there were comparatively few swarms wintering in the coastal areas of Persian Mekran in January-February, 1929; and there was no over-wintering in British Mekran and in Sind. Still, large numbers of locusts migrated in February into British Baluchistan and Upper Persia. In the case of India, had it not been for the appearance of those swarms in spring and later on of the summer flights, it is certain that the intense infestation of 1929 and 1930 might not have been brought about.

Again, in 1930, owing to defective rainfall in August, there was no late breeding and very little of west-bound migration in autumn. Consequently, over-wintering was not observable either in Sind, Punjab or Baluchistan, and according to Predtechensky there were no locusts even in Persian Mekran. In March, 1931, however, swarms coming from the direction of Oman began to appear in Persian Mekran and to move up into Persian and British Baluchistan; reaching Chagai in April. Summer flights began to appear in Sind and the Punjab by June, so that India again became re-infested in the summer of 1931. If these flights apparently of Arabian origin, had not invaded India, the country might have been free of locusts in 1931. There was westward migration in the autumn of 1931, but as the winter rains of 1931-32 failed in the western areas, there was very little breeding in spring, and the summer flights of 1932 were exceedingly few, so that there was a breakdown of the cycle in the summer of 1932. All the above evidence would indicate that Indian outbreaks are often very strongly influenced by Arabian infestations.

Cycle of 1912-1919. During this cycle, there was a complete breakdown in 1915 in India, as on account of failure of summer breeding there was very little of migration flight either towards the west or the east in autumn. All the same, summer flights appeared in 1916 from the west. In 1918, there was a complete failure of rain in the desert, and consequently there were no autumn flights, there being no breeding in summer. Yet spring and summer flights were noticed in 1919, but no summer breeding occurred that year presumably on account of excessive rainfall. The cycle came to an end in 1919, as apparently there were no sufficient re-inforcements from Oman areas in 1920 or, in 1921, which was a year of winter rain-failure.

Cycles of 1889-98 *and* 1900-07. There was a break-down in summer in 1893, presumably due to an exceedingly heavy rainfall preventing summer breeding. There were no west-bound flights in 1893, 1894 and 1895, nevertheless, summer flights were noticed in 1894, 1895 and 1896. Neither summer breeding nor autumn flights were noticed in 1899 on account of monsoon failure; infestation, however, continued in 1900. In 1907 though summer breeding was limited on account of heavy rains, a certain amount of westward migration was noted in autumn. But summer flights did not enter India either in 1908, 1909 or 1910. Apparently all these cases are explicable in terms of the state of infestation of the east Arabian areas.

Period between 1861 *and* 1882. There was a break-down in 1873, when on account of a failure of summer breeding, there was no west-bound migration. Summer flights were not noticed in 1874 and 1875, but occurred in 1876 in which year a new cycle commenced. In 1879 and 1880, winter-spring rainfall failed during two successive seasons, and consequently there were no summer flights from the west, but as a result of good spring rainfall in 1880-81, flights reappeared in 1881. From 1882 to 1885, however, there were none, apparently because there were no locust swarms in the Arabian areas during these years.

Although there is a considerable amount of breeding in the Indian area both in spring and in summer, and the flights that are produced are capable of causing much damage in India, yet it is only a comparatively small proportion of these flights that is capable of continuing the infestation into the succeeding year. Most of the swarms moving east or south are ultimately lost, and it is only those flights that reach the western winter rain-areas—roughly about a third of the swarms produced in India —that are in a position to take the infestation into the year following. If there are no west-bound flights in any year, the outbreak in India would come to a close, in case it is not re-inforced from the western areas by way of summer migration. India would thus be free from infestation only when there are no more swarms left in the western areas for invading India in summer. India is, on the whole, an area of summer multiplication, and being dependent on the western winter-rain areas for the production of spring breeding, is not self-sufficient for continuing the outbreak for more than a season or two. The indications from the data available are that, on the whole, the Indo-Iranian outbreaks should be considered as probably a branch of the Arabian infestations, in view of the circumstance that, though the Indo-Iranian area of locust habitat does possess independent outbreak centres capable of bringing about phase transformation and inciting incipient swarming, the Indian infestations do not appear to be capable of continuing independently for more than a year without receiving periodical re-inforcement in summer from the western areas.

CHAPTER V

PRACTICAL ISSUES

As a result of the studies of past infestations in India, an account of which has been given in the foregoing chapters, a fairly definite advance in our knowledge of locust outbreaks in India may be claimed to have been made. Experience in dealing with locust outbreaks has shown that half the fight will have been won, if a prior warning can be had about the probable time of their appearance. In the earlier years, the suddenness of their apparition put people into a panic, and one had no idea as to how far the flights would reach, nor where they were likely to breed. It was generally believed that once locusts reached a province they stayed and bred there till they perished either as a result of an attack by birds or other natural enemies, or of control measures. Till a regular study of swarm flights in the various parts of India was begun by Cotes in 1889-1890, none had any idea as to the distances covered by the Rajputana-bred swarms in the course of their flights to the east and to the south, or as to the comparative rapidity of such migrations.

In the absence of a general idea in regard to the source of origin of the flights observed, or the laws governing the movements of these swarms, little could, of course, be done in most of the provinces by way of preventive or control measures by the cultivators except by attempting to drive the swarms out of their particular fields.

As a result of the numerous observations and researches carried out during the last three decades, there has been a great advance of knowledge in regard to the laws by which locust outbreaks and the movements of swarms are governed, so that it has now become possible for *warnings* to be issued by central organisations to areas menaced by locusts, sufficiently early to enable requisite precautions being taken in time. Wherever *outbreak areas* have been properly surveyed and delimited, it should, moreover, also be possible to keep them under vigilant watch and check the initial manifestations of gregariousness with a view to nip the nascent outbreaks in the bud.

(A) Swarm Flights and their control

I. *Flights in India and their Origins*

Flights occurring in India fall under three categories: 1. Spring flights, 2. Summer flights, and 3. Autumn flights.

1. *Spring flights and their origin.* Spring flights are concerned with the movements of over-wintered locusts. It is only when late breeding has occurred that over-wintering is observable within Indian limits (as applied to India prior to partition), swarms being found in Sind, Punjab and parts of Baluchistan. Otherwise, over-wintered swarms are generally confined to the southern coastal areas of British and Iranian Baluchistan. With the advance of spring, these swarms become active and move north and north-east from the coastal areas, and reach the northern parts of Persia, parts of Afghanistan, the uplands of British Baluchistan and perhaps ultimately the Punjab and the N. W. Frontier. The swarms from Sind generally move west into Baluchistan, and in the Punjab the movements are either towards the Baluchistan valleys or into the northern districts of the Punjab and into N.W.F. Province. It is these flights that bring about spring breeding in Baluchistan, Persia and Punjab.

2. *Summer flights and their Origin.* The locusts produced in the spring breeding areas of Eastern Arabia, Iran, Afghanistan and Baluchistan go to form the huge flights that are noticed moving into India from the west from May onwards. Perhaps there may be a sprinkling of the remnants of the over-wintered yellow locusts also among these migrants. In India, the locusts produced during the spring breeding in the Punjab and the N.W. Frontier Province also begin to fly from May onwards and take a south-easterly directions towards the United Provinces and Central India. The early swarms from the west are from the southern parts of Baluchistan and Iran, the next wave coming in the later part of May or in June is from the uplands of Baluchistan and from Afghanistan (Kandahar area) and from the Seistan and lower Khorasan areas of Persia, while the flights appearing in July and August are from northern parts of Persia such as Upper Khorasan, and perhaps from Russian Turkmenistan. These summer flights rapidly pass over Sind and Rajputana and may reach the United Provinces, the Central Provinces, and perhaps even Bihar and Bengal. In some years, the swarms may fly south into Berar, Hyderabad and Madras. Flights. reaching Bihar and Bengal in June-July may be carried back by the easterly winds of the Bay monsoon into the United Provinces, the Punjab, Rajputana and even into Sind. It is these swarms that in combination with others arriving from the west, lay eggs in July and August after the fall of monsoon rains in the desert, in the Punjab and in Sind. Flights from the west reach Kathiawar and north Gujarat, directly from Sind and Rajputana, and egglaying may occur if conditions of rainfall are favourable.

3. *Autumn flights and their Origin.* Summer breeding takes place during the months of July, August, September and October. The swarms produced in the Punjab usually find their way in October and November into United Provinces and Central India, and in combination with those originating in Rajputana may reach Central Provinces, Bihar, Bengal and Assam. As regards the Sind-Rajputana area, the locusts bred in the western parts of the desert usually find their way into Baluchistan in the course of the autumn months, whereas those bred in the southern parts reach the Western India States and northern parts of Gujarat. Those produced in the eastern parts of Rajputana generally fly east or south-east into Central India, the Central Provinces and further east. In certain years, especially during the months of September and October, certain developments of wind currents may take the flights south into Hyderabad, Bombay and Madras areas. It is probable that most of these flights ultimately become disintegrated and are lost.

II. *Elimination of flights by controlling the breeding areas*

In dealing with locust infestations, it is common experience that locusts in the winged condition are far more difficult to control than in the hopper stage. Until methods of attacking flying swarms by the use of poison dusts from aeroplanes, as yet only in an experimental stage, are perfected, adult locusts can be destroyed only when resting on plants at night. On the other hand, hoppers are easily controlled by various methods, chiefly trenching and poison-baiting. In the Rajputana area, where the soils are soft and sandy, trenching has been found a very successful method.

(i) The areas affected by *spring flights* in the Indian area are (1) the Punjab and (2) Baluchistan. In the former, spring breeding occurs only when over-wintered swarms are present early in spring, and as over-wintering always results from late summer breeding of the previous

year, there would be little trouble in the Punjab, if late breeding is effectively tackled. As to Baluchistan, little can be done to prevent the spring flights, as they come from south Iran and eastern Arabia and there is no definite information at present about their antecedents.

(ii) It is the *summer migration* from the west that is the real menace to India's crops. Once the flights enter India, they pass rapidly over the whole of north India eastwards up to Bengal, and sometimes south as far as Madras. What is more important, most of the east-bound swarms turn back with the Bay monsoon current and reach parts of North-West India—Punjab, Rajputana or Sind—and breed there, causing much damage to crops. These flights may have bred partly in the Punjab, partly in Baluchistan, but mainly in the spring-brood areas of Iran, East Arabia and Afghanistan. In 1944, according to Pruthi, "though there was no breeding during early spring in Persia or Oman, active breeding had been in progress in Sudan, East Africa and Coasts of the Red Sea throughout the past winter and spring, and India was again unexpectedly invaded by swarms from Arabia during March-April, 1944," [Pruthi 1944]. This would indicate that, unless breeding is effectively controlled in the western areas, especially in Arabia, the ingress of western flights cannot be prevented.

(iii) *Autumn flights* are the results of summer breeding and since most of it takes place within Indian limits, its control should not be difficult to arrange, as it is more or less an interprovincial affair. Of the summer breeding grounds, the most important is the Sind-Rajputana desert, which would appear, in view of the vastness of the area and the almost ideal conditions it presents for the breeding of the desert locust, to have formed the main source of Indian swarm infestations. But it is a tract of little value from the point of view of crop production, supporting a very spares population and has, on the whole, no better means of transit that the ubiquitous camel. As the desert areas of Rajputana have been under the administrative control of numerous small States, facilities either for centralised observation or for co-ordinated control were non-existent in the past. Although intensive control operations had been undertaken in the surrounding provinces of Sind, Punjab and the United Provinces in past years, there was no effective check on locust infestation, as a whole in India, owing to the fact that the most important breeding area of the locust had been left out of account.

To remedy this defect the Government of India expanded in 1941 (soon after the recent outbreak of 1940-46 began), the Locust Warning Organization into a well organised Locust Control Organization, designed for keeping the activities of locust swarms all over India under close observation and for co-ordinating the anti-locust operations of the various states and provinces affected under the directions of a Central Director of Locust Control. As a result of the efficient check thus effected all over the area, autumn flights were almost completely eliminated during the years 1942, 1943, 1944 and 1945 [Pruthi, 1944, Rao, 1945]. Not only were swarms absent in autumn in the areas east or south of Rajputana, but very few flights were observable even in the west in Sind and Baluchistan during these years.

(B) Control of Inoipient Swarms in Outbreak Areas

In view of the importance of checking locust infestations before they have spread outside the areas of their origin, the Fifth International Locust Conference that met at Brussells in 1938, recommended the formation of an international organization composed of staff financed

by the co-operating governments, whose functions were to be chiefly (1) the permanent supervision of all outbreak areas—whether known or suspected, and (2) the immediate destruction of incipient swarms observed.

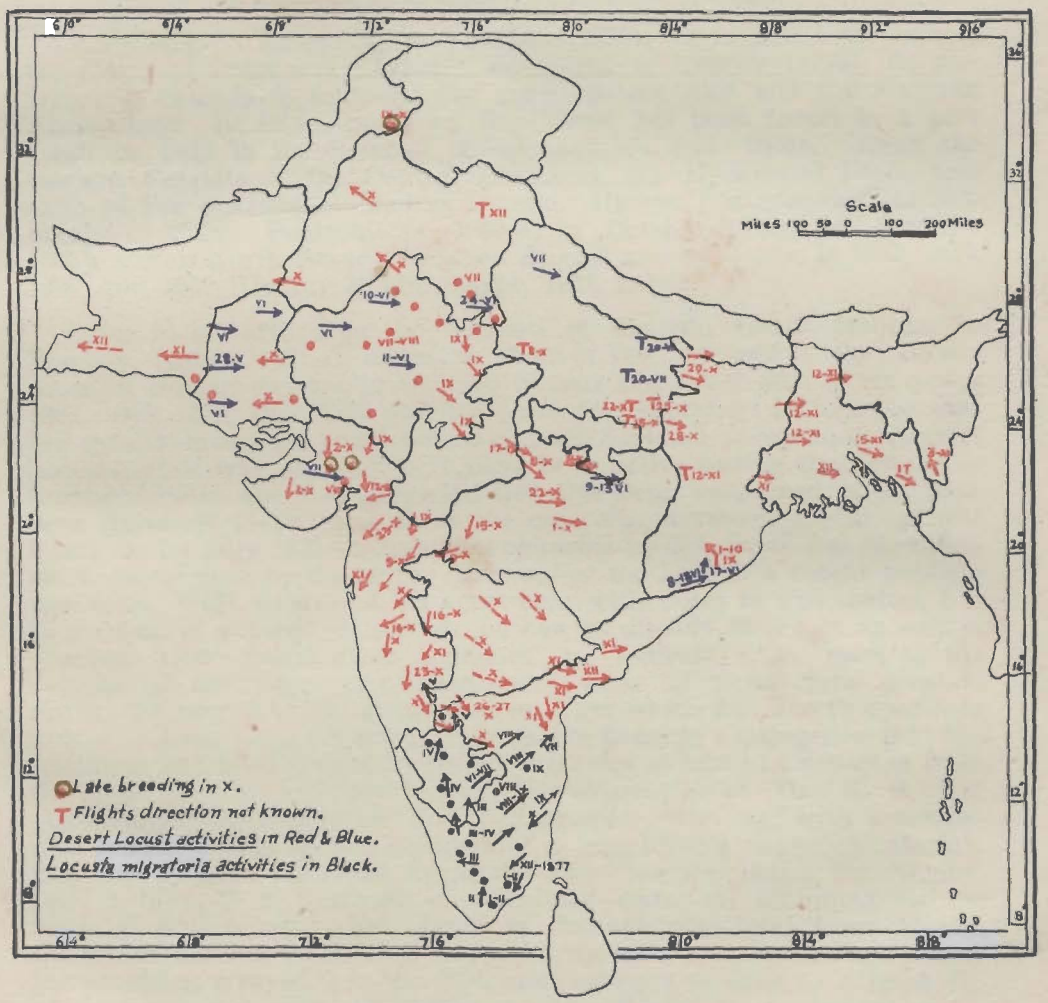
In regard to the Indo-Iranian region of infestation of the desert locust, which also includes the eastern parts of Arabia, very little is known about the exact conditions of the outbreak areas beyond Indian limits. Except for the observations made by Predtechensky [1935-b] in 1929-31 on swarm movements in Persia, and for the surveys made by Maxwell-Darling [1937] in eastern Arabia and by Hussein [1936] in Hediaj and Yemen, there is no definite information available in respect of the suspected existence of outbreak centres nor is there any local organization, except perhaps in Iran, for keeping such centres under observation. Even within the Indian areas, unless a fairly adequate staff is provided, it would be difficult to keep the great barren, thinly populated expanses in Baluchistan and Rajputana under efficient watch and for checking the infestation in the early stages.

In connection with the detection and checking of incipient swarms, however, it may be stated that there are many practical difficulties which will have to be thoroughly studied and overcome if the method of preventive control should prove a success. In South Africa, where this method was tried on a large scale, against the Brown Locust, it is stated [du Plessis, 1939] that, during the season 1937-38 it proved only a partial success, as (1) owing to various difficulties in the effective destruction of incipient hopper bands by means of poison-bait, not more than 50 to 60 per cent of the bands could be destroyed, and (2) quite large numbers of scattered hoppers—which often remain outside the hopper bands,—attained the adult stage unchecked, it being evidently uneconomical to attempt to destroy hoppers of the *solitaria* phase found distributed all over the area. Unless, therefore, further practical experience is gained, it will not be possible to say how far the preventive control of the incipient outbreaks would be a practicable proposition.

Observations made in regard to the functioning of the various outbreak centres notified within the Indian area of Indo-Iranian region, would show that there are several areas in Baluchistan and in the Indian Desert that are capable of giving rise to incipient swarms. It is, however, evident that such cases of crowded breeding are not, generally, on a scale large enough to produce the populations needed for giving rise to a new cycle of infestation. Since locust individuals bred from such outbreak centres have the habit of migrating long distances at the change of the seasons, they may be presumed to join hands with individuals whatever their phase—produced from similar other centres and reach suitable breeding areas in a different rain belt. In case, conditions are favourable, they may increase here in such numbers as gradually to become grouped into larger and larger integrations, which may after further migration ultimately unite to form large swarms.

It is, therefore, probable that, in tracing the origin of Indian outbreaks, one should take into account the activities not only of the outbreak centres within Indian limits but also of those situated in other countries organically connected with India in respect of normal flight circuits. There is, thus, a need of an internationally controlled watch of the various outbreak centres and of an international organization for checking all significant cases of incipient swarming *as and wherever* they may arise.

In Indian infestations, the summer flights of western origin that occur regularly during outbreak years are of particular importance as it is these that are responsible for the continuation of Indian outbreaks from year to year. At present, there is no definite information as to where these flights come from, and in case, as it is surmised, they do come from long distances—perhaps from Sudan or from East Africa—India should be as much interested in locust control in those far off areas as she is in such control operations in the Indo-Iranian areas.



LOCUST SITUATION IN INDIA IN 1878

SECTION XII—MISCELLANEOUS ISSUES OF THE LOCUST PROBLEM

CHAPTER I

OTHER LOCUSTS IN INDIA

BESIDES the Desert Locust, there are two other locusts to the incidence of which the Indian sub-continent is subject, which are some times capable of inflicting a great deal of damage to cultivation. Of these, one is *Patanga succincta* (Linn.) (otherwise known as the Bombay Locust) and the other is *Locusta migratoria* Linn. (the Indian Migratory Locust).

I. *Patanga succincta*—THE BOMBAY LOCUST

Distribution. According to Fletcher (1920), "it is found throughout the plains of India and Ceylon". According to Uvarov (1928), its distribution extends to southern and south-eastern Asia and the Malayan Archipelago. In India, however, this locust has been found in a pest condition only in the Bombay Presidency, Central India, Berar, the western districts of the Central Provinces, the Hyderabad State, and some of the districts of Madras Deccan. Uvarov has recorded its outbreaks in Malay Peninsula in 1930-32 in October-November [Uvarov 1933], and in North Borneo, between August and February, in 1933, 1934, 1936, and 1937 [Uvarov & Milnthorpe, 1937, 1939].

Cotes in his article on the "Locusts of Bengal, Assam, Madras & Bombay, [Cotes, 1891,a], mentions about a few records of the occurrence of certain swarms in western Bengal and Bihar during the years 1862, 1865, 1873, 1877, 1878 and 1881, and had expressed his opinion that the species concerned could not have been *Acridum peregrinum* (Desert Locust), as it was not known to have been active during these years in Northern India, and had suggested that the locust concerned might have been *Acridium succinctum*, as in one case, *viz.*, a swarm appearing near Patna on 1st July 1877—a specimen collected by Mr. Scott was identified as *A. succinctum* by Saussure. The writer too had, in a recent publication [Rao, 1943], expressed his agreement with Cotes in this matter, but as a result of subsequent studies, he has, as already stated in an earlier chapter, now found clear evidence to indicate that most of the swarms of the years mentioned were those of *Schistocera gregaria* Forsk. In regard to the Patna swarm, from which Mr. Scott's specimen is said to have been collected, there is the possible contingency that the specimen had been caught by people after the swarm had departed from the locality. This is supported by the experience of Dr. K. B. Lal (Government Entomologist, United Provinces), who met with a similar case recently. The writer is indebted to him for the following information conveyed in his letter dated the 13th October, 1944: "In August, 1941, I brought a specimen of Acrididae (later on identified by the Imperial Entomologist, New Delhi as *Patanga succincta)* from Aligarh Dt. which had been collected there shortly before. I do not know how the specimen strayed into the U.P. and managed to exist in Aligarh Dt. because although only one specimen was collected (by a non-entomologist, who mistook it for the desert locust) it is likely that there should have been some more of this species roundabout. My efforts to get some more specimens collected failed."

Though there are no authentic records of the presence of swarms of the Bombay Locust in the plains of northern India, stray specimens of isolated individuals have been collected from many locafities in this area

in the past. In the course of locust surveys made during the period 1932 to 1939, stray migrants have been collected on several occasions in the desert areas, mostly in the autumn and winter months. One specimen was collected as far west as Dadhar in Kachhi in March, 1938 [Rao & Bhatia, 1939]. Records of localities of collection include Pusa (Bihar) in August, 1917, Coimbatore on several occasions, Nilgiris (November 1907) and Laccadives, 1929.

Life History and Habits. The Bombay locust differs from the desert locust in many important particulars. It has only one brood in the year. Adults of the new generation appear in September-October, but remain sexually immature till next June. With the advent of monsoon rains in June in the Bombay areas, they begin to pair and lay eggs. Soft clays are preferred for oviposition, and eggs may be laid either in grasslands or among cultivation. According to Lefroy [1906], eggs hatch in 6 to 8 weeks, and the hoppers go through 7 to 8 moults, taking 8 to 10 weeks to reach the adult stage. Its *hoppers are not gregarious,* but remain scattered among grasses or among crops. Wings are assumed by September-October, after which they usually collect together to form swarms, and begin to migrate towards the south-west along with the north-easterly winds prevalent at that period. During the cold weather, they are mostly found in the forests of the Western Ghats, and are comparatively inactive. From February onwards they begin to fly actively, and by April & May, their flights may reach the northern districts of Bombay, parts of Hyderabad and the northern districts of Madras Deccan. By June, swarms may in some years reach Central India, Berar and the western parts of the Central Provinces. With the fall of monsoon rains, egg-laying may occur in suitable places.

Records of Past Infestation. Data regarding swarms of the Bombay locust have been obtained from the Indian Museum Notes (Cotes, 1891, a), from Lefroy's Memoir (Lefroy, 1906) and from the season and crop reports of the Bombay Gazette and the Gazette of India. Interesting information on the invasions of *Patanga* in 1880-1883 and in earlier years in Nasik, Poona, Ahmednagar and other districts is to be found in the volumes of the Bombay Gazetteer (Old Series). From the data collected, it would appear that, like the Desert Locust, the Bombay Locust is also subject to some sort of distinct, though less marked, periodicity in its appearances. The data prior to 1873 are too fragmentary in character to be of much use for purposes of study. "Continued drought and great swarms of locusts" are said to have contributed to a gradual failure of crops in Belgaum Dt. during 1787-1796. During 1799 and 1800, Buchanan [1807] recorded a flight of 'red locusts' in May at Mundiam in Mysore. Swarms are said to have appeared in Poona in 1835, and in the Panch Mahals in 1845. In 1853-54 locusts are said to have eaten up the early harvest in Nasik. In 1864 and 1865, locust damage is reported from Belgaum Dt., and in June 1865, a locust swarm was reported to have passed through Nandigama in Kistna Dt. (Madras).

From 1873 onwards, data collected from the season reports of the Bombay Gazette provide more satisfactory information. Between 1873 and 1875, swarms were noted in Belgaum, Poona and Khandesh districts. There were no reports in 1876-77 on account of the great drought.

A new cycle of *Patanga* infestation would appear to have started after the heavy rains of September-October, 1877 and the good monsoon of 1878, and the first swarms were reported from Kolaba Dt. in February-March, 1879. The locust gradually increased in numbers till the peak was reached in 1882-83. Swarms had disappeared by the end of 1884.

The first symptoms of a re-appearance of swarms were noticed in 1899, but there was a break in the development on account of the low rainfall of 1899. The locust made its appearance again in 1901, since which year there was a continuous outbreak till 1908. Since 1910, only stray swarms have been reported: in 1910-11, in 1915, in 1920, and in 1925-26.

Information on the occurrence of *Patanga* flights in Madras Presidency was obtained from the printed Proceedings of the Revenue Board of Madras preserved in the Madras Record Office.

Range and Direction of Patanga *Swarm Migrations.*—As there has not been any serious invasion since 1908, information on the movements of *Patanga* swarms is based mainly on the observations made by Lefroy in 1903-1905, and by various persons during the outbreak in 1882-1883. During the cold weather, the swarms are generally found confined to the forest areas of the Western Ghats, occasional flights taking them to the Konkan, Goa, Belgaum and Dharwar areas. From March onwards they become active again, (1) during May and June, flights from Dharwar and Kanara may reach Hyderabad State, and the districts of Bellary, Anantapur, Kurnool, Guntur and Kistna in Madras and Chitaldrug in Mysore, (2) with the prevalence of the south-west winds from the middle of May, flights *via* Bijapur, Sholapur and Ahmednagar Dts., may reach parts of the Hyderabad State, Berar and Central Provinces, and (3) others *via* Nasik and Khandesh, may reach north Gujarat, west Central Provinces and Central India.

In 1904, flights reaching Nasik, Khandesh, Berar and Central Provinces in June were found to settle down and breed on the fall of satisfactory monsoon rains. Possibly, breeding might have occurred in Aurangabad and other neighbouring districts of Hyderabad, but there are no records, nor are there any in respect of breeding in the southern districts of Bombay: Satara, Belgaum, Sholapur and Dharwar. There is, of course, no likelihood of breeding occurring in the districts of Bellary, Kurnool and Guntur, as there is but little rain here in June or July. No information is available as to what happens to the swarms that reach Bellary, Kurnool, Guntur and Kistna and the eastern parts of Hyderabad: possibly they fly further east into the hilly areas of Eastern Ghats or into the hills of Central Provinces. From the records available, however, in regard to the Central Provinces, there are no indications that swarms penetrate east of Nagpur, Chindwara and Chanda (80°E. Long.), which was the limit reached in 1904. As regards the northern limits of migration, swarms may reach as far as Dhar and Jhabua (23°N. Lat.) in Central India, and as far as Godhra (23°N. Lat.) in Panchmahals. In the year 1883, however, swarms were reported from Raghugarh (24.30° N. Lat. & 77·15°E. Long.) in Guna Agency during the week. 4th to 10th July, in Central India. In that same year, swarms were said to have appeared during the week ending 11th September, in Mau Pargana of Jhansi Dt. (United Provinces) (25.30° N.Lat. & 77.20° E. Long.). As in 1883, swarms of the desert locust were not reported from anywhere in India, there is little doubt that the swarms found in Jhansi were those of the Bombay Locust, and if this view is correct, this is the only authentic instance of swarms reaching the United Provinces. So far as available data go, there are no records of *Patanga* swarms flying north of 25·30°N. Lat. or east of 80°E. Long. A study of the normal progress of the south-westerly winds during the monsoon period shows that beyond the latitude of Bhopal, the south-west current is affected by the seasonal trough of low pressure lying to the south of the United Provinces and gets deflected towards the east or south-east, so that there is not much

likelihood of swarms being conveyed by the south-west current from the southern areas of Central India directly into the United Provinces.

Breeding usually extends from the month of July to middle of September, and the new generation is ready to fly by October. As at this time, north-easterly winds generally prevail in the areas of western Central Provinces, in the southern parts of Central India and in Bombay, *Patanga* swarms would fly westwards or south-westwards into Bombay territory and ultimately reach the Western Ghats or Sahyadri Range. During the winter months, swarms may visit Konkan (where sometimes whole areas of coconut palms are said to be stripped), Goa, Karwar, Belgaum and Dharwar. Presumably some of the flights are driven off the shore and carried long distances into the sea at times when high north-east winds prevail, since *Patanga* is known to be present in some of the larger Laccadive Islands, where coconut palms are said to be attacked. There does not appear to be any authentic instance of swarms of the Bombay Locust visiting the areas of Madras Deccan during the autumn period, and the statement made by the writer to that effect in an earlier publication [Rao, 1943] has since been found to be based on incorrect data.

The Phases of the Locust: Its Outbreak Centres.—As already mentioned, several instances of isolated individuals of this species were collected in the Sind-Rajputana desert areas in the past, and an examination of these specimens has showed that these are biometrically distinct from individuals collected from swarms, indicating that they probably represent the *solitaria* phase of this species. Very little however is known as to where these *solitaria* forms breed or how far their range of flights extends. Since similar isolated individuals have been collected from many parts of India, it is likely that their breeding grounds are wide-spread, and not merely restricted to the grass areas of Western Ghats. Perhaps similar breeding areas may be found among the Aravalis, the Vindhyas, the Satpuras and the Eastern Ghats, and possibly also in parts of Kathiawar. Since this species has only a single generation in the year, like the Red Locust of Africa (*Nomadacris septemfasciata*) its swarms can be built up only if there is a succession of favourable years in regard to breeding. The fact that the pest had assumed serious dimensions twice during the past seventy years: 1878-1884, and 1898-1908, shows that it is an insect whose developments deserve close watching; while the circumstance that there have been, since 1910, no serious developments, for reasons at present unknown, is a subject well worth investigation. This cannot be explained satisfactorily until the habits and ecology of the solitary phase of this locust are fully studied.

II. *Locusta migratoria* Linn.—The Indian Migratory Locust

The Migratory Locust (*Locusta migratoria* L.) is another of the potential pests of India that may at times flare up into a serious menace. Specimens of the solitary phase of this locust are met with almost all over India, but as, in general appearance and behaviour, there is little to distinguish it from any ordinary grasshopper, it has not apparently attracted the attention of entomological workers. Apparently, there has been no published record of any unusual local multiplication of this species in India.

In October, 1937 damage to crops by locusts was reported from Sirohi State and from Mehsana Dt. of Baroda State and on examination it was found that the damage was caused not by the Desert Locust, but by hoppers of *Locusta migratoria* [Rao & Bhatia 1939]. It was at first

supposed that the outbreak was the result of local multiplication but as it was reported that the infestation was not noticed prior to September, and as it was also found that similar attacks on cereal crops had occurred at about the same time in parts of the Kaira Dt. and of Palanpur and Idar States, it becomes evident that it was a case of an invasion of this species from outside, though an ingress of swarms had not anywhere been observed. Fortunately, valuable observations had already been made that year by locust research staff in the areas of Baluchistan, Sind and Rajputana on the occurrence of heavy breeding of the solitaries of *Locusta* in spring in the hill valleys of Baluchistan, and subsequently of heavy summer breeding in the desert areas of Bikaner and Jaipur in July-August. Apparently, adults bred in the valleys of Baluchistan had migrated as individuals into Bikaner and had bred there, after the fall of monsoon showers, and by the end of August, large numbers of adults of the new generation were noticeable in the Bikaner-Jaipur areas. These were, however, found to have disappeared from these places, when, after a long break in the monsoon during August, a depression from the Bay accompanied by heavy rainfall passed, early in September, through Rajputana towards the southwest. Evidently these adult locusts had migrated with the depression into Sirohi, Palanpur and Idar areas and had laid eggs in suitable areas and had started the infestation. By the first week of November, locusts assuming wings in the Sirohi, Mehsana and Idar areas were found also disappearing, and it is presumed that they had mostly departed in a westward direction as unusually large numbers of *Locusta* adults were noticed in parts of Sind and Baluchistan in November-December. There was a fair amount of crowded spring breeding in the Bolan area in the spring of 1938, but there was no further development, as the monsoon of 1938 was very defective in Rajputana.

Locust Invasion of Madras in 1878. A short account by Cotes of a great invasion of locusts in Madras in 1878 in the Indian Museum Notes (Cotes, 1891, a,), prompted the writer to seek the original records on the subject, and if possible, to collect further information, with the object of studying the data in correlation with rainfall and seasonal winds. A great many of the printed Proceedings of the Board of Revenue, Madras, were perused at the Madras Record Office with the kind permission of the Madras Government, as also the season and crop reports published in the Gazette of India, the Mysore Gazette and the Fort St. George Gazette relating to the period 1877 to 1880, at the Bangalore Secretariat with the kind permission of the Government of Mysore. As a result of an analysis of the information collected in correlation with available meteorological data, the writer was able to arrive at certain tentative conclusions in regard to the origin and progress of the infestation of 1878, a brief account of which was given in a recent publication [Rao, 1943]. It is proposed to give a short resume of the account incorporating therein certain changes found necessary in the light of further information collected.

The identity of the Locust. Cotes observed in his note on the subject: "Nothing seems to have been ascertained at the time of the invasion as to the determination of the species concerned, though the insects were spoken of in one of the reports as belonging to the species *Locusta migratoria*." A set of the specimens furnished by the Madras Central Museum as representing the locust of 1878 were found to contain no less than six species of Acrididae (mostly common grasshoppers) of which the only representative of the locust type was a specimen of '*Pachytylus migratorius* or *P. cinerascens*.' Doubtless, the furnished

by the museum was from random collections made by lay people from fields after the main swarm had departed, but the presence of the single specimen of *Locusta migratoria* is certainly significant. Moreover, in the body of the records of the invasion, there are references to the colour of the hoppers as "reddish brown" or "black and gold", which are certainly distinctive of *Locusta*. In one case, the males are described as very small and the females as large and brown (distinctive of the *transiens* and *solitary* phases of *Locusta*) and in another case, the males are said to have been yellow and the females brown (which is true of the *gregaria* phase). There seems to be little doubt that the Madras Locust of 1878 was *Locusta migratoria*, but no statement can be made as to its identity from the point of view of the race or sub-species of this variable species. It would be of interest to know whether the affinities of the Indian sub-species are with the African *migratorioides* or the Eastern *manilensis*.

The history of the invasion. The available information on the invasion relates to the period—December, 1877 to December, 1878, and may be considered under the following heads: (1) Winter breeding, (2) Spring flights and spring breeding, and (3) Summer flights and summer breeding.

1. *Winter Breeding.* The earliest information on record is the occurrence of heavy infestation by hoppers in *cholam* (Sorghum) and *cumbu* (*Bajri—Pennisetum*) in Perambalur and Trichinopoly taluks of Trichinopoly Dt. in December, 1877. In November, 1877, however, there were reports of infestation by locusts and some kind of hoppers in *cholam* in Cuddappa Dt., and it is possible that the hoppers might have belonged to *Locusta migratoria*, and if so, in view of the earlier fall of rains (from September ownwards) in this area, this might have been the beginning of the infestation. Hopper damage to cereal crops in January-February, 1878 in Kamuty, Rajasingamagalam and Pallimadam Tqs. of Madura Dt. and in Ottapidaram and Sattur Tqs. of Tinnevelly Dt. was next reported. In the Tinnevelly Dt. it was stated that "in a army of red-brown creatures were marching slowly along, eating every leaf of the *cumbu* crop. Cotton was not touched." At Paralachi in Madura Dt., hoppers could hardly be kept out of the houses. Apparently the hoppers reached the winged stage by February when the adults began to fly about. During November, December and January, which is the period when the retrating monsoon is active in the south of the Madras Presidency, the winds are generally north-easterly and were presumably favourable for carrying the swarms from the north towards the southern-most parts of South India.

2. *Spring Flights and Spring Breeding.* Adults appearing in the course of January, February and March, 1878 formed swarms, which soon began flying about. Winds prevailing in the south of the Peninsula during February, March and April are variable, but are mostly easterly, south-easterly or southerly. The main direction of the flights was north or north-west. In March, heavy flights were reported from parts of the Anamalai Hills. They passed over the Madura district into Coimbatore and Malabar Dts. from the south. During March and April, swarms flew across the Nilgiris and the Satyamangalam Hills and reached Wynad, Coorg and Mysore in successive waves. In the Mysore State, swarms were recorded in Mysore, Hassan and Kadur districts by the middle of March, and in the Chitaldroog Dt. in the third week. Flights were reported from the Bellary district on 22nd March in the Kudligi Tq., and a week or two later in the Hospet, Hadagali and Harpanahalli taluqas. By the end of March, swarms were observed at Kod and Kalghatgi in the Dharwar district of Bombay; during April, flights were observed round-about Dharwar and Gadag and by the last week of the month, they reached Saundatti in Belgaum Dt.

Good rainfall was registered in April and May, in Coimbatore. Madura and Tinnevelly districts, in most parts of the Mysore State and in the Bellary Dt., and as a result, egg-laying occurred in many of these areas:— in Coimbatore Dt. (Udumalpet, Podanur, Mettupaliem), in Malabar Dt. (Walayar, Palghat Tq.), in Madura Dt. (Periyakulam, Palni, Dindigal, Ammaiyanaickanur), in Tinnevelly Dt. (Tinnevelly, Tenkasi), in Bellary Dt. (Hadagali, Harpanahalli), and in Mysore (Hassan, Kadur, Chitaldrug, Tumkur). Hoppers were noticed in all the above areas during May-June, in some cases causing damage to crops. The areas of breeding would appear to have been situated mostly in a strip of upland country, about 50 miles wide, running south to north from 9° Lat. to 15° Lat. North parallel to the line of the Western Ghats Range.

3. *Summer Flights and Summer Breeding.* From the middle of May, the prevailing winds are south-westerly in these areas. As the hoppers of the spring brood gradually assumed wings, the young swarms were found to take flight in the course of June-July. As the south-west monsoon was then in full swing, the flights were mostly towards the north-east, the swarms bred in Madura and Tinnevelly being carried into Trichinopoly and Tanjore; those from Malabar and Coimbatore into Salem, North Arcot, South Arcot and Chingleput; those in south Mysore, passing through Bangalore and Kolar into Chittoor and Nellore district; and those from Kadur, Chittaldroog and Tumkur, passing through Anantapur and Cuddappa districts, into Nellore.

As the central and eastern districts of Madras fall within the rain-shadow of the Western Ghats, the rainfall in these areas during the south-west Monsoon period is relatively poor. Rain in July was comparatively light, but in August and September, a fair amount of rain fell in some of the central districts, and as a result thereof, some breeding occurred in August in Krishnagiri Tq. of Salem Dt. and in September in the vicinity of Chittoor. Owing to such a paucity of breeding, a gradual diminution in the number of swarms and in their comparative density was observable by September, 1878. During October-November, the few swarms recorded were those reported from Chingleput, North Arcot, South Arcot and Tanjore, and at this time, the general trend of movements was north-east to southwest. In November, light breeding apparently occurred in Madurantakam taluq of Chingleput Dt., but as the north-east monsoon rains were defective in 1878, swarm breeding did not, apparently, occur except perhaps on a very small scale, so that locusts presumably reverted to the solitary phase, and thereby brought the outbreak of 1878 to an end.

The probable Origin of the Infestation of 1878. In the absence of a full knowledge of the habits and ecology of the solitary phase of this locust in its breeding areas in South India, it is difficult to say how exactly the outbreak of 1878 had originated. Even at the time of the invasion, it was the opinion of more than one responsible officer that the locust trouble had some connection with the occurrence of abnormally heavy rainfall during the last four months of 1877, following a long period of scanty rainfall during 1876-77. It is surmised that during the years 1876 and 1877, while the general drought lasted, the breeding of migrating insects like locusts had been restricted to and concentrated in a few places where local rainfall had occurred. Generally even in years of drought, hill areas receive a fair amount of rainfall as compared with the plains, and it is presumed that this had helped the formation of small concentrations of *Locusta* on some of the hill areas. In more than one instance, it was stated in the reports on the locust invasion of 1878 that breeding had occurred in the grass areas on the hill-flanks, and in some cases it was

also said that locust hoppers had invaded cultivation from the hills. According to Uvarov (1936), the outbreaks of the Oriental Migratory Locust (*Locusta migratoria manilensis* Mey.) in Borneo and the Philippines, are associated with the grassy areas that develop on the hills as a result of shifting cultivation. Since this type of primitive cultivation is also in vogue on the hill-ranges of South India, it is not improbable that the outbreak centres of the invasion of 1878 had developed on some of the main hill-ranges, such as the Western Ghats, the Shevaroys, the Kollimalais and the Javadis. Incipient swarms formed on the hill-flanks in 1876-77 had possibly migrated into the eastern districts during the prevalence of the south-westerly winds, and had bred there during the heavy rains of September, and had subsequently been swept down towards the southern districts such as Trichinopoly, Madura and Tinnevelly by the heavy cyclonic winds of the north-east monsoon during November and December. Favoured by the high rainfall, dense egg-laying had possibly followed, leading to the development of heavy infestation in the southern districts.

After 1878, there has been no serious invasion of *Locusta* in South India, but in some of the Proceedings of the Board of Revenue, Madras, there are references to the appearances of locust swarms in the southern districts. In 1881, a small swarm is said to have appeared in Madura Dt. (Tirumangalam Tq.) in April; in 1885, a swarm was reported in Madura Tq. in July, another in Trichinopoly Tq. attacking sugarcane, *ragi* and paddy in August (flying west to east), and a third in South Arcot Dt. (Vriddhachalam Tq.) breeding in fields in September, and in 1886, locusts are said to have attacked gingelly crops in Madura Dt. (Periakulam Tq.) in June. In the last case, specimens sent were said to have been identified as the "true locust" (possibly *Locusta migratoria*) by the Superintendent, Madras Central Museum. It is not possible to be sure about the species concerned, but from the coincidence in regard to the time of occurrence and the circumstances connected therewith, it should be considered not unlikely that the species had been *Locusta*, as in 1878.

Though the locust has not again appeared in a serious form, there is every likelihood of a recurrence of the outbreak if conditions should again be favourable for its development.* If we take into account the fact that this species had suddenly loomed up as a serious pest in the Rajputana and Gujarat areas in 1937, the need of studying the seasonal distribution, habits and ecology of the solitary phase of this locust under the very varied conditions of the different parts of India cannot be too much emphasized.

---

* It may be interesting to record here that a comparatively small outbreak of locusts was reported in the identical parts of Ramnad district in February 1954, when the specimens collected were definitely identified as *Locusta migratoria* Lidn.—*Author.*

CHAPTER II

SUNSPOT CYCLES AND LOCUST PERIODICITY

It is a matter of common knowledge that many of the natural phenomena noticed on the face of the earth are ultimately traceable to the energy derived from the radiations of the sun, and it is not surprising that an explanation of the countless fluctuations in various earthly phenomena, such as changes in the weather and variations in the growth of plants and the breeding of animals, has been sought in the variations in the quality and quantity of solar radiations. Emanations from the sun are, on the other hand, found to vary with the number of sunspots noticeable on the sun's disc. Sunspots have been described as 'terrific cyclonic storms in the solar atmosphere generating powerful electro-magnetic fields', and the number of sunspots gradually increases for some years and then decreases, a single cycle of such changes being usually of the average duration of eleven years and four months. Observations have shown that the occurrence of magnetic storms, auroral displays, and the fading out of radio transmissions in some years are all connected with an increase in sunspot activity. Harlan T. Stetson [1937] has shown in his fascinating book on 'Sunspots and their effects from the Human Point of View' that the growth of plant life varies directly with the increase in the number of sunspots, while in the case of animals there is an inverse variation. On the whole, an increase of sunspot activity produces greater cloudiness and thus greater rainfall, and the effect of such a variation is clearly seen in the growth-rings of large trees, and in the rock records of past ages. Swinton [1883] has adduced evidence to show that periods of prevalence of locusts in the past years in Europe and Africa generally coincide with those of sunspot minima, while Criddle [1932] found that outbreaks of grasshoppers in Manitoba (Canada) are associated with periods of sunspot minima, and Richmond [1938] also noted a similar correlation in British Columbia. Uichanco [1936] observed a fairly marked negative correlation between solar activity and locust fluctuation in regard to the swarms of the Oriental Migratory Locust (*Locusta migratoria manilensis* Mey.) in the Philippine Islands.

Uvarov [1931], while discussing the periodicity of outbreaks among insects, observes: "The fact that the fluctuations in the numbers of certain insects coincide to some extent with the 11-year sunspot periods can scarcely be disputed." In regard to the simultaneous mass appearance of the Desert Locust in the enormous area stretching from Morocco and Senegal to Kenya, Egypt, Palestine, Persia and Northern India in 1915-16 and again in 1927—1930 after an interval of about 11 years, he is of opinion that they suggest the existence of a general cause, which can be sought in general climatic fluctuations, connected perhaps with sunspots, but not with local conditions.

The writer had in 1938, with the data available to him at the time, worked out a graph showing the curve of fluctuations in locust infestation in northern India and compared it with the sunspot fluctuation curve for those years [Rao, 1938]. He had then come to the tentative conclusion that there was, on the whole, a negative correlation between the curves of locust infestations and sunspot numbers, and, that except in the case of certain years—1929-30, 1896—98 and 1905—07, there was great locust activity while the sunspot numbers were below 30 and decline was noticeable with the rise of sunspot numbers. Another conclusion reached was that initial outbreaks marking the commencement of a new cycle were always located within the period of sunspot lows, and occurred *just before, during, or just after* the year of sunspot minimum.

Pasquier [1942], recognising the importance of a forewarning in respect of a coming invasion for preparing the country beforehand to meet it efficiently, has been interesting himself in the correlation of locust infestations with sunspot data. He has found that in North Africa there have been nine locust cycles, since 1943, corresponding to nine solar cycles, but does not think there is any negative correlation between the curves of locust infestation and of sunspots. He agrees, however, that there is almost always a linkage between the origins of outbreaks of the desert locust and the periods of sunspot cycle minima, which is based on the circumstance that the greatest variability of ecological conditions obtains only during the epoch of sun-spot minima. He has also martialled out a great deal of statistical evidence to prove that besides at the period of sunspot minima, a secondary period of high variability of ecological conditions develops at the close of the epoch of sunspot maxima, which would explain the occurrence of a secondary rise of infestation in some years, as for instance in 1929-30, 1906-07, and in the recent cycle 1940—45. He further suggests that, at least, some of these cases might be considered to be double ones, the second semi-cycle beginning only in the second critical period.

Since 1938, much additional information on Indian infestations has been collected and studied. The long expected outbreak commenced rather suddenly in the autumn of 1940 and has provided much matter for reflection. As a result of his recent studies of past Indian cycles, the writer has moreover had to revise as stated in an earlier chapter, his views in regard to the individuality of Indian infestations, since they seem to be, on the whole, dependent on the ingress of swarms from the west for their continuation from year to year. They should rather be considered as a branch of the Arabian infestations, and if this view be correct, it would perhaps be more to the purpose to try and establish a correlation between the Arabian outbreaks and the sun-spot cycles.

In preparing the graph of locust infestation curves in 1938, the writer calculated the fluctuations of each individual year on the basis of the approximate area covered by the outbreak. During the present studies, he has endeavoured to take into consideration all the various aspects of Indian infestations, so as to arrive at as accurate an estimation as possible under the circumstances, giving approximate values for each as shown below:—

I. *Occurrence of Over-wintering*		*Infestation Values allotte*			
	Baluchistan	1			
	Sind	1			
	Punjab	1			
	Gujrat	1			
	Rajputana	1			
	Other areas	1	Total	6	
Damage done by over-wintering swarms			Do.	3	9
II. *Occurrence of Spring Breeding*					
(Value includes damage done):	Baluchistan	5			
	Sind	4			
	Punjab	6			
	N.W.F.P.	2			
	United Prov.	4	Total		21

III. *Occurences of Summer Flights.*

Baluchistan, Sind, Rajputana, Punjab, United Prov., Central. Prov. Bombay, Madras, Bihar & Bengal each 1 point . .	10		
Damage done by summer flights .	5	Total	15

IV. *Occurrence of Summer Breeding.*

(Value include damage done)	Baluchistan	5	
	Sind	4	
	Rajputana	10	
	Punjab	6	
	United Prov.	6	
	Gujarat	2	
	Central India	2	
		Total	15

V. Occurrence of Autumn Flights.

Baluchistan, Sind, Punjab, Rajputana, C. P., U. P., Bihar, Bengal, Assam, Madras, Gujrat and Bombay ; each 1 point .	12		
Damage done by autumn swarms .	8		20
Grand Total .			100

Infestation Values for various years: 1861—1940

Calculated on the above basis, the following are the values arrived at for the various years. For some of the years prior to 1889, full particulars of infestation under all the items have not procurable, and in such lars of infestation under all the items have not been procurable, and in such cases, an estimation of values has been made for known items, and the total has been shown as "*Over n*".

Years	Values	Years	Values	Years	Values	Years	Values
1862	Over 23	1871	10	1881	Over 9	1891	39½
		1872	25½	1882	Over 5	1892	22
1863	Over 34	1873	23½	1883	Nil	1893	23½
1864	Over 10	1874	2	1884	Nil	1894	7
1865	Over 12	1875	2	1885	Nil	1895	5
1866	Over 10	1876	20	1886	Nil	1896	26
1867	Over 6	1877	Over 14½	1887	Nil	1897	40½
1868	Nil	1878	Over 38½	1888	2	1898	30
1869	Over 33	1879	27½	1889	26½	1899	7
1870	Over 14½	1880	Over 13	1890	37	1900	14

Years	Values	Years	Values	Years	Values	Years	Values
1901	30	1911	5	1921	Nil.	1931	21
1902	27	1912	10	1922	4	1932	4
1903	30	1913	28	1923	5	1933	2
1904	11	1914	27	1924	4	1934	
1905	20	1915	20	1925	3	1935	2
1906	36	1916	13	1926	15	1935	N il.
1907	31	1917	10	1927	33	1937	Nil.
1908	2	1918	2	1928	17	1938	Nil.
1909	2	1919	6	1929	40	1939	Nil.
1910	1	1920	1	1930	54	1940	7

The Infestation Graph

The Graph (Plate 56) is the representation of a continuous curve showing the fluctuations of annual means of relative sunspot numbers in successive cycles from 1796 to 1944, on which a curve of the fluctuations of locust outbreaks in India between the years 1862 and 1944 (based on the above mentioned infestation values) has been super-imposed. Stray data regarding locust infestation in some years prior to 1862, such as for 1796, 1803, 1810, 1811, 1812, 1821, 1826, 1834, 1835, 1843-44 and 1845, have also been shown in their proper places, and been connected together by a purely hypothetical curve. It may be stated, however, that the present graph does not differ much from that of 1938 in all essential particulars.

1. There have been 8 solar cycles since 1861, and there have been eight more or less corresponding locust infestation cycles.

2. If the solar cycle of eleven years be divided into four epochs, as done by Pasquier [1942], *viz.* (1) epoch of sunspot minima (4 years), (2) epoch of sunspot increase (2 years), (3) epoch of sunspot maxima (3 years), and (4) epoch of sunspot decrease (2 years), it is seen that the development of the initial swarms marking the beginning of new cycles would appear to have occurred mostly in the epoch of sunspot minima, *e.g.* 1869, 1876, 1888, 1900 and 1912. In the case of the I Cycle (1861-1867), there is no information as to the exact beginnings of this cycle; and in the case of 1926, it is probable that the real beginning of this cycle was in the year 1922 or 1923; and in the case of the beginning of the current cycle, although the year 1940 comes under the epoch of sunspot decrease, it should probably have to be considered as the beginning of a secondary rise, or of the second demi-cycle of Pasquier, the first demi-cycle which manifested itself in 1935 in India, having proved abortive.

3. Comparing the curves of locust infestation with those of sunspot fluctuations, a certain amount of inverse correlation is noticeable between them, which is fairly clear between the years 1876 to 1924, the locust curves showing a rise while the solar curves are on the decrease, and a fall when the latter are on the increase. As already pointed out, there are erratic rises in infestation between 1896 and 1898, between 1905 and 1907, and between 1929 and 1931, which might be called secondary demi-cycles according to Pasquier. As pointed out in earlier chapters,

these rises were purely due to invasions in summer by swarms coming from the west, evidently derived from Arabian infestations (partly from over-wintered stocks in Oman during spring flights, and partly in the shape of summer flights of spring-bred swarms from Persia), no over-wintering swarms having been noticeable in India during the winters of 1895-96, 1904-1905 and 1928-29. Consequently, these rises are to be traced to factors that had been operative in Arabian areas rather than in India. The rises found in the periods 1861–65 and 1871–73 are probably also of the above category.

It is rather striking that all those years for which information on locust incidents during the period prior to 1861 has been available have with one exception, *viz.*, 1803, fallen within the period of sunspot lows.

4. In the case of the recent cycle, the beginnings of swarm activity manifested themselves in 1940 in India, and in 1939 in the southern territory of Algeria (Pasquier, 1942). It should, however, be recalled that outbreak centres had formed in the Red Sea areas of Sudan during the winter of 1933-34 (Maxwell-Darling, 1936), that light breeding either of the soiltaries or of gregarious forms had been observed during the winters of 1934-35 and 1935-36 in the same areas, as well as swarm breeding in Eritrea and Abyssinia in the summer of 1935, [Uvarov, 1935; Uvarov and Milnthorpe, 1937], that gregarious breeding occurred in the Red Sea areas in the winter of 1936-37, followed by the appearance of swarms in Trans-Jordan in April, 1937 and the development of an outbreak in the Western Desert of Egypt (after heavy spring rains) in June, 1937 and that some gregarious breeding occurred in the Red Sea areas in the winter of 1937-38 also [Uvarov and Milnthorpe, 1939]. This would show that there has been a continuity of breeding (though light) from 1933 up to 1939. It is possible that there had been an interchange of populations between Algeria and Egypt, and Red Sea and East Arabia during this period, which resulted in the initiation of the outbreaks in India and Algeria. It might perhaps be considered that the real beginning of the present cycle had occurred in the winter of 1933-34 during the epoch of sunspot minima, although swarm activity actually commenced only in 1939-40.

Similarly, during the previous cycle there was good winter rainfall in the Red Sea areas in the winter of 1921-22, which, it is presumed, had been followed as usual by the formation of incipient swarms; and possibly the outbreak of 1923 in Mekran and the entry of swarms at Kermanshah in Persia in the same year were derived from the Red Sea breeding, so that the VII cycle (1926—32) should be considered to have actually begun in the epoch of sunspot minima, though the major outbreak did not develop at that time, but only 3 years later.

As to the linkage of the period of sunspot minima with the production of incipient swarms there is clear evidence in India in the case of two other species of locusts also. Between September, 1877 and December, 1878, which falls within the minimum sunspot epoch, there was an extraordinary outbreak of *Locusta migratoria* in South India; and this period also saw the beginnings of the mass-multiplication of *Patanga succincta*, which culminated in the heavy infestation of 1882-1883 in Bombay, Berar and Central India. The next outbreak of *Patanga* occurred during the period 1898—1908, the initial multiplication of which was noticed to have commenced during the year 1898, also falling within the sunspot minimum period. While *Locusta* and *Schistocerca* are able to have two or more broods in a year, by reason of their ability to migrate to favourable regions of rainfall at the change of the seasons, and are, thus capable of rapidly multiplying into serious proportions within 2 or 3 seasons, locusts

like *Patanga* having only one generation in the year are able to achieve a marked rise in population, only if they happen to have a succession of years favourable for multiplication.

Though there is, thus, fairly positive evidence that the minimum epoch is propitious for initiating outbreaks, it is not clear how exactly both these are linked together. It is difficult to envisage a direct connection between locust breeding and the decrease of sunspots, unless the sunspot radiations are supposed to have a prejudicial effect on the reproductory powers of locusts. Otherwise, there can be only an indirect influence through the medium of terrestrial weather, since locust breeding is entirely dependent on favourable conditions of rainfall and temperature. It is known that an increase of sunspot activity has often entirely opposite effects on tropical as contrasted with temperate regions, as also on summer-rain as against winter-rain belts, so that there is bound to be a correspondingly great variation in locust developments in the different regions. There is a further complication in view of the ability of locusts to migrate from one zone to the other at the change of the seasons. It is, therefore, difficult to generalise in this matter with regard to the effect of sunspots on locusts through their influence on the weather.

As to the ultimate aim of predicting the time of appearance of coming invasions in terms of the development of the sun spot cycles, the present state of our knowledge would, in the opinion of the writer, unfortunately preclude the possibility of any exact prevision being seriously considered. There is no doubt a fair accumulation of past data in regard to Indian infestations, but in view of the present indications that Indian outbreaks are dependent for their continuance on re-inforcements from the Arabian infestations, it would be futile to take up the question of predicting future outbreaks, until exact information is available in regard to the origin of the infestations, the position of the outbreak areas, the direction of the seasonal migrations and the nature of rainfall and winds in respect of the vast Arabian region.

While discussing the appearance of the earliest swarms in French North Africa, during the current cycle, Pasquier [1942, a] expressed the view that the possibility of the swarms having come from the Red Sea areas could not be excluded; and in connection with the lag generally noticed in the appearance of the first swarms in the French North African area in most of the cycles of North African infestations as compared with the Indian outbreaks, [Pasquier 1942], he was of opinion that it might be "considered to be the result of a spread of invasions from east to west, and might go to support the hypothesis in regard to the eastern origin of the flights affecting Algeria." Pasquier's views would thus appear to strengthen the indications mentioned already in regard to the primary importance of the Arabian-Sudanese areas of locust habitat, in the initiation of new outbreak cycles.

APPENDIX

COMMON NAMES OF THE DESERT LOCUST IN DIFFERENT LANGUAGES

Languages	Adults	Hoppers
English . . .	The Desert Locust . . .	Hoppers
French	Le Criquet Pelerin (Pilgrim Locust).	Les Sauterelles
Russian . . .	Pustinoyi Saranchi . . .	Lichink
Italian	La Cavalette	
Spanish . . .	La Langosta	Saltadores
German. . . .	Africanische Wanderheuschrecke (African Locust).	Larven
Arabic	Al Qarad (Egypt) ; Al Jarrad (Arabia); "Abu Najdi"—*Najdi Locust* (Iraq).	Dibba
Persian	Malakh-i-Daryayi (Sea Locust)	
Baluchi	Madagh	
Punjabi	Makri	Poong
Sindhi	Makkad	
Hindi	Tiddi	'Reekhan'; 'Phake' (Rajputana)
Sanskrit . . .	Salabha; Pathanga . . .	
Marathi . . .	Tol; Naktode	
Oriya	Jhitika	
Telugu	Midtha ; Midtha Dandu .	
Kanarese . . .	Midchi ; Jitte	
Tamil	Vittil ; Vettukkili . .	

REFERENCES

Adams, Lt. Col. Sir Archibald. 1899. *Western Rajpuana States*, London, 1899

Admiralty, British 1932. *'The Red Sea Pilot'* 1932, Published by the British Admiralty, London.

Aitken, E. H., 1907. "*Gazetteer of Sind*", Karachi, 1907.

Andrewes, E. A., 1916 "Locust swarms in Darjiling and Terai Dts.," *Qly. Jl. Ind. Tea Assam* 1915.

Ballard, E., Mistikawy. Eff. A. M. & El Zoheiry, M. S. 1932. "The Desert Locust—*Schistocerca gregaria*—in Egypt," *Tech & Sc. Ser. Plant. Prot. Sect. Bulletin No. 110, Cairo*, Egypt

Banerji, B. N. 1931. "Meteorology of the Persian Gulf and Mekran," *Indian Meteorological. Department, 1931.*

Bell, Horace, 1899. 'The Great Indian Desert,'' *As. Qtly. Rev. VIII.* July 1899.

Bhatia, D. R. 1939. "Influence of Dust-storms on the migrations of the Desert Locust," *Indian Jl. Ent.* 1, *1 & 2, June 1939.*

Bhatia, D. R., 1940. 'Observations on the biology of the desert locust in Sind Rajputana desert area—The preferred food plants of the Locust,' *Indian. Jl. Ent.* 2 (2) *Decr, 1940.*

Blanford, W. T. 1876-a. "Physical Geography of the Great Indian Desert ," *Jl. As. Socy of Bengal.* 45, *1876*, pp. 86-103.

Blanford, W. T. 1876-b. "Eastern Persia—An Account of the Journey of the Persian Boundary Commission—1870-72. Vol. II—Zoology and Geology, London, 1876.

Blanford, W. T. 1901-a. Chapter on "Zoology" "*The Imperial Gazetteer of India, The Indian Empire*" Vol. 1. p. 213.

Blanford, W. T. 1901-b. "The Distribution of Vertebrate Animals in India, Ceylon and Burma," *Trans. Roy. Soc. of London. Vol. 194. B*, (1901).

Board of Agri. in India 1930. "*Proc. Board of Agri. in India*", Pusa, Dec. 1929.

Bodenheimer, F. S., 1930. "Studien Zur Epidemiologie, Okologie u. Physiologie der afrikanischen Wanderheuschrecke (*Schistocerca gregaria* Forsk)," *Zeit. fur angew. Ent. B. XV.3.29.*

Bodenheimer, F. S., 1932. "Uberblick uber Gesamtokologie der afrikanischen Wanderheuschrecke (*Schistocerca gregaria* Forsk)", *Biol. Zentralblatt. 52.* ix-x-1932.

Bodenheimer, F. S. 1936. "Factors controlling locust populations", *Proc. IV Inter Loc. Conf. April, 1936*, Cairo.

Bodkin, G. E. 1929. "Locust invasion of Palestine during 1928," *Bull. Ent. Res. XX. Aug* 1929, P. 123.

Buchanan, F., 1807. "*Journey from Madras through Mysore, Canara and Malabar*", London. 1807.

Burkill, I. H. 1909. "*A Working List of Baluchistan Flowering Plants*", Calcutta.

Burt, B. C. & Dutt, G. R. 1930. "The Desert Locust in India, 1929-30". *Agr. Jl. India* XXV, pp. 417-425.

Chapman R. N. 1931. "*Animal Ecology with special reference to insects*" London.

Christophers, Major S. R. 1921. The Distribution of Mosquitoes in relation to the Zoo-geographical Areas of the Indian Empire, "*Proc. Fourth Ent. Meeting, Pusa, Feb. 1921.*

Coleman, L. C. & Kannan, K. Kunhi 1911. The Rice Grasshopper—(*Hieroglyphus banian Fabr.*) *Bull. Mysore Dept. Agr. Ent. Ser. No. 1.*

Coleman, L.C. 1911. "The Jola or Deccan Grasshopper—(*Colemania sphenarioides Bol.*) *Bull. Dept. Agr. Mysore. No. 2.*

Conference, III Inter. Loc. 1934. *Proc. III International Locust Conference*, London, Sept. 1934, Secy. Colonies, London.

Conference, IV Inter. Loc. 1937. *Proc. IV Int. Loc. Confce*, Cairo, Apl. 1936 Ministry Agr. Egypt.

Conference, V, Inter. Loc. 1938. *Proc. V Int. Loc. Confce.* Brussells, Aug-Sept. 1938, Roy. Belg. Min. Des. Colonies.

Cornish, Vaughan 1897. "On the formation of sand-dunes", *The Geographical Jl. IX pp.* 278-1897.

Cotes, E. C. 1891. "The Locust of North-Western India", *Jl. Bomb. Nat Hist. Soc.*, Vol. VI.

Cotes, E. C. 1891, a. "The Locusts of Bengal, Madras, Assam and Bombay", *Ind. Mus. Notes*, II, No. 4 Sept. 1891.

Criddle, N. 1932. "The correlation of sun-spot periodicity and grasshoper outbreaks" *Can. Field. Nat.* 46 ; 195-99.

Duarte, A.H. 1938. "Problems of the growth of the African Migratory Locust", *Bull ent Res. 29*(4) Dec. 1938.

Elliot, Sir George 1906. *Climatological Atlas of India*, 1906.

Faure, J. C. 1923. "The life history of the Brown Locust—*Locustana pardalina*", *Bull. Transvaal Univ. Coll., Pretoria, No.* 4—1923.

Faure, J. C. (1932). "The Phases of Locusts in South Africa", *Cult. ent. Res.* 23(3) Sept. 1932.

Faure, J. C. 1934. "The swarming of *Schistocerca gregaria* (Forskal) in the Union of South Africa and in South West Africa in 1934", *Proc. III Int. Loc. Conf. London 1934.*

Faure, J. C. 1935 "The life history of the Red Locust," *Union S. Africa Dept. Agr. & For. Bull 144.*

Fletcher, T. B. 1928. "Report of the Imperial Entomologist'—*Sc. Rept. Agr. Res. Inst. Pusa* 1926-27, p. 63.

Fletcher, T. B. 1931. "Locusts in India", *Proc. Bd. Agr. Pusa*, 1929, ; 124-156.

Floyer, E. A. 1882. "*Unexpected Baluchistan*", London, 1882.

Fox, H., 1940. "*Schistocerca americana* (Drury) unusually abundant in New Jersey during autumn of 1939"—*Ent. News, 51, pp.* 43-45.

Frere, Sir Bartle, E. 1870. "Notes on the Runn of Cutch & neighbouring regions," *Jl Roy Geog. Soc. Vol. XL.*, 1870 p. 194.

Gazetteer, Baluchistan, District, 1907. "Chagai Dt.", p. 152.

Gazetteer, Baluchistan District, 1907. "VI. Sarawan" , Bombay, 1907, p. 145.

Gazetteer, Baluchistan District, 1908. "Quetta-Pishin Dt.". p. 373, pp. 212-13.

Gazetteer Bombay Presidency, 1880. "V, Cutch, Palanpur & Mahikantha", 1880. pp. 173-176.

Gazetteer, Bombay Presidency, 1880. "VIII, Kathiawar," 1880, 'Famine'.

Gazetteer, Bombay Presidency, 1880. "XXII. Khandesh," 1880, p. 182.

Gazetteer, Bombay Presidency, 1882. "VII, Baroda", 1882, 'Years of scarcity'.

Gazetteer, Bombay Presidency, 1883. "XVI, Nasik", 183, p. 296.

Gazetteer, Bombay Presidency, 1884. "XXI, Belgaum" 1884, p. 280.

Gazetteer, Bombay Presidency, 1885, "XVIII, Poona," 1885, p. 476.

Golding, F. D. 1934-a. "On the Ecology of Acrididae near Lake Chad", *Bull. ent. Res. 25* (2) July, 1934.

Golding, F.D. 1934-b. "Methods of Field Surveys in Locust Research", Appendix 4, *Proc. Int. Loc. Confce. London*, 1934.

Gupta, R. L. 1939. "A note on Phase Transformation in *Locusta migratoria*", *Indian Jl. Ent Vol. I Parts* 1 & 2. June 1939.

Hamilton, A. G. 1936. "The relation of humidity and temperature to the development of three species of African Locusts," *Trans. Roy. ent. Soc. London, LXXXV.* 1, 1936.

Hertz, M & Imms, A. D. 1937. "On the Responses of the African Migratory Locust to different Types of Background," *Proc. Roy Soc. London. Ser. B. Vol. 828 Vol. 122 p. 281--297.*

Hooker, J. D. & Thompson 1885. "Introductory Essay to Flora Indica", *Vol. I 1885.*

Hooker, Sir J. D. 1907. "Botany". The Imperial Gazetteer of India, *Indian Empire, Vol. I, P. 157-212.*

Husain, M. Afzal. 1933. "Presidential Address to the Section of Agriculture, Indian Science Congress", Patna, January, 1933.

Husain, M. Afzal, 1941. "Studies on *Schistocera gregaria.* Account of Locust Visitations in India during the last cycle, 1926-1931", *Indian. Jl. Ent.* 3 (2) December, 1941, pp. 285-320.

Hussain, M. A. & Ahmad, Taskhir 1936-a. "Studies on *Sch. gregaria* Forsk--II, The Biology of the Desert Locust with special relation to Temperature," *Ind. Jl. Agr. Sc.* 6 (2) April 1936.

Husain, M. A. & Ahmed, Taskhir 1936-b. "Studies on *Schistocera gregaria* Forsk,—VI, in fluence of Temperature on the Intensity and Extent of Black Pattern in the Desert Locust hoppers bred crowded," *I. J. Agri. Sc.* 6 (3) June 1936.

Husain, M. A., Ahmad, Taskhir & Mathur, C. B. 1940. "Studies on *Schistocerca gregaria* Forsk,—X : Role of water in the Bionomics of the Desert Locust", *I. Jl. Agri. Sc.,* 10 (6) Dec. 1940.

Husain, M.A. & Mathur, C.B. 1936. "Studies on *Schistocerca gregaria* Forsk—V. Pigmentation and Physical Exertion," *I. Jl. Agri. Sc.* 6 (3) June 1936.

Hussein, M. 1938. "An Expedition to Arabia for Locust Investigations," *Proc. V. Int. Loc Confce Brussels.*

Imms, A. D. 1930. "*General Text Book of Entomology*", London 11 Ed. 1930.

Isaac, P.V., 1929. "Report of the Imperial Entomologist"—*Sc. Rep. Agr. Res. Pusa* 1927-28 p. 74.

Isaac, P. V., 1931. "Report of the Imperial Entomologist", *Sc. Rep., Imp. Agri. Res. Inst. Pusa* 1929-30, p. 76.

Jhanjhua, N.A., 1940. "Bionomics and Control of the Black-headed Cricket, *Gryllulus domesticus,* L., in USTA Colony", *Agr. & Live St. in India,* 9 (6) Nov. 1939.

Johnston, H. B. 1926. "A further contribution to our knowledge of the bionomics and control of the Migratory Locust *Schistocerca gregaria (peregrina,* O1). in the Sudan,". *Ent. Sect. Welcome Trop. Res. Lab. Bull No.* 22.

Karandikar, K. R. 1939. "External structures of the Desert Locust." *Jl. Univ. Bom.* 7 (5) March, 1936.

Key, K. H. L., 1936. "Observations on the life-cycle of *Locusta migratorioides*", *Bull ent. Res. 27, pt. 1,* Febry. 1936.

Key, K. H. L. & Edney, E. Berry 1936. "Precocious adults resulting from the omission o the 5th instar in *Locusta m. migratorioides* (R. & F.)" *Pr. Roy. ent. Soc. London Ser, A., Gen Ent. Vol.:II, pts.* 3-5, 30th June 1936.

Kennedy, John, S., 1939. "The Behaviour or the Desert Locust (*Schistocerca gregaria Forsk* in an outbreak centre.". *Trans. ent., Soc., London* 89 (10) 27th Sept., 1959.

King H.H. 1929, *Bull ent. Res.* 20 P. 99, 1929.

King, H. H. 1934. "Destruction of Locusts in flight etc." *Proc. III Int. Loc. Conf.* 1934 London.

Kunckel d' Herculais, J. 1893, "Invasions des Acridiens *vulgo* Sauterelles en Algerie". *Min Instr. Publ. et., Agr.* 1893.

La Touche, J. H. D. 1902. "Geology of Western Rajputana," *Mem. Gen,. Survey India.*

Lea, A. & Webb, D. van. V., 1939. "Field observation on the Red Locust in 1936-37"—*Sc., Bull. Dep. Agr. S. Afr.* 139.

Lean, O. B. 1931. "The effect of Climate on the Migrations and Breeding of *Locusta migratorioides* in Nigeria." *Bull. ent. Res.,* 24 (4) December, 1931.

Lefroy, H. M. 1906, "The Bombay Locust,' (*Acridium succinctum L*)"—*Mem Dep. Agr. Ind. Ent. Ser. Vol. I,* 4.

Lespes, L. Regnier, P., & Rungs, C., 1930."Contribution a l'etude des phases chez le Criquet Pelerin (*Schistocerca gregaria* Forsk) *C. R. Acad. Sc. Paris, Tom. 191 No.* 49 10th Nov. 1930.

Mann, H. H. & Burns, W. (1927). "The Locust Attack of 1926-27 in Sind, Kathiawar and Gujarat," *Agri. Jl. India.* **22**. *325—332.*

Mason, C. W. & Lefroy, H. M. (1927). "The Food of Birds in India." *Mem. Dep. Agri. India Pusa,* Jany. 1912.

Maxwell-Darling, R. C. (1934). "Solitary Phase of the Desert Locust in North Eastern Kordofan (Anglo-Egyptian Sudan), *Bull. ent. Res.* **25** (1) March 1934.

Maxwell-Darling, R. C. (1936-a). "The Outbreak Centres of *Sch. gregaria* on the Red Sea Coast of the Sudan." *Bull. ent. Res.* **27** (1) *Feb. 1936.*

Maxwell-Darling, R. C. (1936-b). "A short reconnaissance of Northern Darfur (A. E. Sudan) with regard to *Sch. gregaria* Forsk," *Bull. entl. Res.* **27** (1) *pp. 71—76.*

Maxwell-Darling, R. C. (1937). "The Outbreak Areas of the Desert Locust (*Sch. gregaria* Forsk) in Arabia," *Bull. ent. Res.* **28** (4) December 1937.

Medlicott, H. B. & Blanford W. T. (1879). "Manual of Geology of India," Part I, 1879.

Melis, Antonio. (1934). "Il Grillastro Crociato," *Atti. R. Accad. Georgofili. XXX. 1933.*

Mosauer, Walter, (1932). "Reptilians and Amphibians of Tunisia," *Publ. Univ. Calif. Los Angeles—Biol. Sciences. Vol. 1, p. 3 pp. 40—64.*

Mukerji, S. & Batra R. N. (1938). "Post-embyonic Development of Eye-stripes and the number of larval Instars etc.," *Proc. V. Int. Loc. Confce. Brussels,* 1938.

Munro, J. A. & Saugstad, S. (1938). "A measure of flight capacity of grasshoppers," *Science—88 No. 2290.* 18th Nov. 1938.

Murat, M. (1927). "Vegetation de la zone predesertique en Afrique centrale (Region du Tchad) No. 12, Alger, (1937). *Bull. Soc. Hist. Nat. Afr. Nord. T. XVIII,* 1937.

Nikolskii, V. V. (1925). "The Asiatic Locust," *Leningrad,* 1925.

Oldham, R. D. (1893). "Manual of the Geology of India," II Edn, pp. 455-458.

Olivier, A. G. (1801). "Voyage dans l'Empire Ottoman, l'Egypt et la Perse", Paris, (Agasce) 1801-1807, *pp. 388-89.*

Pasquier, Roger, (1942) : a. "Les Sauterelles pelerines : L'invasion actuelle, Les recherches—La lutte", *L'Agria,* No. 99. Avr. 1942.

Pasquier, Roger, (1942). "Prevision et periodicite des invasions de la Sauterelle pelerin en Afrique du Nord", *Bull. dela Soc. des Agricultures d. Algeria* 85. No. 509, Avr. Dec. 1942.

Plessis, C. du, 1939. "The Incipient outbreaks of the Brown Locust in 1937-38 with special reference to Biometrical analysis," *Dep. Agr. For. S. Afr. Sc. Bull. 209,* 1939.

Predtechensky, S. A. (1935-a). "Studies on the Desert Locust in Central Asia and the Trans Caucasus in 1929-30", *Bull. Pl. Prot. Leningrad, No. 11,* 1935.

Predtechensky, S.A. (1935-b). "The Annual Cycle of the Desert Locust (*Sch. greg.*)—Its Migrations and Periodicity in Persia and adjacent countries of Tropical and Sub-tropical Asia" *Leningrad. 1935. Bull.* No. 12.

Pruthi, H. S. (1941). "A fresh cycle of the Desert Locust in India", *Curr. Sc.* **10** (11), Nev, 1941, *pp. 479—483.*

Pruthi, H. S. (1944). "War against Locusts in India", *Curr. Sc.* **13** (7), *pp. 174-176,* Jul. 1944.

Rao, Y. Ramchandra, (1920). "Lantana Insects in India", *Mem. Dep. Agr. Ind., Ent. Ser. V No. 6. June* 1920, *p. 294.*

Rao, Y. Ramchandra (1921). "*Oxya velox*": *Proc. 4th Ent. Meeting, Pusa,* 1921.

Rao, Y. Ramchandra (1933). "Mekran—possibly the country of origin of the Great Locust Invasion of Sind in 1926"—*In. Jl. agr. Sc.,* **3** (5), 1933.

Rao, Y. Ramchandra (1936). "The Locust incursion of 1935 in N. W. India—Its significance in the study of the Locust problem"—*Ind. Jl. agr. Sc.* **6** (5), 1936.

Rao, Y. Ramchandra (1937-a). "Study of Migration among the Solitaries of the Desert Locust (*Sch. gregaria* Forsk)". *Proc. 4th Int. Loc. Confce—Cairo,* 1937.

Rao, Y. Ramchandra (1937-b). "Some Outbreak Centres of *Schistocerca* in Mekran": *Proc. 4th Int. Loc. Confce.,* Cairo. 1937.

Rao, Y. Ramchandra (1938). "A preliminary note on a study of locust infestations in N.W. India since 1863 in relation to sun-spot cycles"; *Proc. V Int. Nat. Locust Conf., Brussels* 1938, XXXI.

Rao, Y. Ramchandra (1940). "Occurrence of green Algae on the wings of locusts", *Ind. Jl. Ent.* 2, 93-94.

Rao, Y. Ramchandra (1941). "Some observations on the Periodicity of Locust Invasions in India". *Pres. Address—Section of Entomology, Ind. Sc. Cong.*, Benares, Jan. 1941.

Rao, Y. Ramchandra (1942). "Some results of Studies on the Desert Locust (*Schistocerca gregaria* Forsk) in India", *Bul. ent. Res.* London, 33, 241-265.

Rao, Y. Ramchandra (1943). "The need of planning on an all-India basis in certain aspects of Agricultural Entomology", *Pres. Address—Sect. Agr. Sciences, Ind. Sc. Congress*, Calcutta, Jan. 1943.

Rao, Y. Ramchandra (1945). "The areas of origin of locust flights in the different parts of India with reference to the question of their control", *Curr. Sc.* February, 1945, 31-33.

Rao, Y. Ramchandra (1948). "A Review of Past Locust Infestations in South India". *Jr. Madras University* Sect. B. Vol. XVIII, 1 July, 1948.

Rao, Y. Ramchandra & Gupta, R.L. (1939). "Some Notes on Eye-stripes in Acrididae" : *Ind. Jl. agr. Sc.*, 9, (5), Oct. 1939.

Rao, Y. R. & Bhatia, D. R. (1939). "Probability of Seasonal Migration among the solitary phase individuals of *Locusta migratoria* in North West India." *Ind. Jl. of agr. Sc.* 9 (1), Feb. 1939.

Richards, P.B. (1931). "Locust Problem in India", *Proc. Bd. Agr. India*, Pusa, 1929, *pp. 161-187.*

Richmond, H. A. (1938). "Some notes on the periodicities of certain insects in relation to the Sun-spot Cycle". *Proc. Ent. Soc. Brit. Columbia*, 16th Feb. 1938.

Roonwal, M.L. (1936). "On the existence of two different types of striped eyes in *Schistocerca*", *Current Science*, 5 (1) *p. 24.*

Roonwal, M.L. (1945). "New Hypotheses for the Prediction of the Swarming of the Desert Locust", *Bull. ent. Res.* 35 (4) : 391, 1945.

Roonwal, M. L. (1946). "On the existence of two colour-types in the adults and hoppers of the solitaria phase in the desert Locust, *Schistocerca gregaria* (Forskal); *Rec. Ind. Mus XLIV* (4). 399-374.

Roonwal, M. L. (1946). "On variation in the number of hind-tibial spines in the Desert Locust, *Schistocerca gregaria* (Forskal). Orthoptera, Acrididae)", *Ind. Jl. Ent.*—8 (1) : 71-77.

Roonwal, M. L. (1946). "On a new phase character, the metasternal interspace, in the Desert Locust, *Schistocerca gregaria* Forsk (Orthoptera, Acrididae); *Proc. R. Ent. Soc. Lond.* (A), 21(1-3); 13-15.

Roonwal, M. L. (1947). "Variation and structure of the eyes in the Desert Locust (*Schistocerca gregaria* Forsk)", *Proc. Roy. Soc. London* (Ser. 3.) Vol. 134 (1947); 245-275.

Smith, Major Euan (1873); "The Perso-Afghan Frontier Commission 1871-72", *p. 382.*

Smith, C.J. B. (1939). "Field observations on the Brown Locust in an outbreak centre." *Dep. Agr. Forestry. Sc., Bull., No.* 5, March 1939.

Statistical Atlas of the Bombay Presidency : 1925.

Stetson, H. T. (1937). "Sunspots and their effects from the Human Point of View", New York, 1937.

Stuart Baker, E.C. (1926). "Birds"—*Fauna of British India, Vol. III, p. 30.*

Swinton, A. H. (1883). "Data obtained from solar physics etc. applied to elucidate locust multiplication and migration" : *III Rep. U.S. Entomological Commission, Dep. Agr., pp. 65-85.*

Talbot, G. (1939). "Butterflies Vol. I," *Second Edn. Fauna of British India*, March 1939.

Thomas, J. G. (1941). "The relative size of the eye as a phase character in the African Migratory Locust", *Bull. ent. Res.*, 31 (14), *pp. 431-433*, Jany. 1941.

Tryon & Pilsbury, (1906). "Manual of Conchology," *Acad. Nat. Sc. of Philadelphia, Vol. 18. Achatinidae.*

Uichanco, L. B., (1936). "Secular trends of locust outbreaks in the Philippines and their apparent relation with Sunspot Cycles". —*The Philippine Agriculturist, 35: pp. 321-356.*

Uichanco, L. B. & Gines R.B. (1937). "A Biometrical study of the adult components of Philippine locust swarms," *Phillippine Agriculturist, 26 pp. 231-289.* 1937.

Uvarov, B. P. (1921). "A revision of the Genus *Locusta* L. (*Pachytylus*, Fab.) with a new Theory as to the Periodicity and Migration of Locusts." *Bull. ent. Res.* 12, *pp. 135-163*, 1921.

Uvarov, B. P. (1924). "Some new and interesting Orthoptera in the collection of the Ministry of Agr. Cairo." *Tech. & Sc. Serv. Bull, 41. Cairo, 1924.*

Uvarov, B. P. (1928). "Locusts and Grasshoppers—A Handbook for their study and Control," *Imp. Bureau Ent. London.* 1928.

Uvarov, B. P. (1931). "Insects and Climate" : *Trans. Ent. Soc., London.* Vol. 79, 1931.

Uvarov, B. P. (1933-a). "The Locust outbreak in Africa and Western Asia in 1925-31", *Econ. Adv. Counc.* London, January 1933.

Uvarov, B. P. (1933-b). "The locust outbreak in Africa and Western Asia in 1932", *Econ. Adv. Counc.* London Oct. 1933.

Uvarov, B. P. (1934). "The locust outbreak in Africa and Western Asia in 1933", *Econ. Adv. Counc..* London, September 1934.

Uvarov, B. P. (1935). "The locust outbreak in Africa and Western Asia in 1934", *Econ. Adv. Counc. London,* July 1935.

Uvarov, B. P. (1937). "Biological and Ecological Basis of Locust Phases and their practical application," *Proc. IV Int. Loc. Confce. 1936 Cairo,* 1937.

Uvarov, B. P. (1947). "The migratory locust in England in 1946 "; *Proc. R. ent. Soc. Lond (A)* 22(4-6); 35-37.

Uvarov, B. P. & Milnthorpe, W. (1937-a). "Locust outbreak in Africa and Western Asia in 1935." *Econ. Adv. Counc.*, March 1937.

Uvarov, B. P. & Milnthorpe, W. (1937 "Locust outbreak in Africa and Western Asia in 1936." *Econ. Adv. Counc.* Oct. 1937.

Uvarov, B. P. & Milnthorpe, W. (1939).). "Locust outbreak in Africa and Western Asia in 1937." *Econ. Adv. Coun.* March 1939.

Van Schalwijk H.A.D. (1939). "The Status of *Wohlfahrtia euvittata* Vill. (Diptera Sarcophagidae) as a parasite of the Brown Locust," *Jl. ent. Soc. S. Africa*, Vol. II, pp. 18-35, Oct. 1939.

Vayssiere & Lepisme (1939). "Observations on the Desert Locust in Lab. of Locust Biology." *Bull. Soc. Hist. Nat. Afr. Nord.* 1939. Alger.

Volkonsky, M. (1937). "Elevage et croissance larvaire du criquet Egyptien (*Anacridium aegyptium* L.)," *C.R. Soc. Biol. Inst. Pasteur Alger,* CXXXV. 1937. page. 739.

Volkonsky, M. (1939). "Stries ocularies et ages larvaires chez les Acridiens," *Arch. Inst. Rev. App. Ent. A.* Sept. 1939.

Wadia, D. N. (1919). "Geology of India for Indian students." *Chapter XXII.*

Waloff, Z. (1940). "The Distribution & Migrations of *Locusta in* Europe". *Bull. ent. Ress* 31, (3), Nov. 1940.

Waloff, Z., 1946. "A long range migration of the Desert Locust from Southern Morocco to Portugal with an analysis of concurrent weather conditions." *Proc. Roy. ent., Soc.* 12 (10-12): 81-84.

Webb Ware, Lt. Col. F.C. (1915). "Locusts in Baluchistan," *Agrl. Jl. India.* 10 (2) Apl. 1915.

Williams, C. B. (1933). "Observations on the Desert Locust in East Africa from July 1928—to April 1929," *Ann. App. Biology, XX. 3 pp. 463-497, August, 1933.*

Willis, H. R. (1939). "Painting for determination of grasshopper flights," *Jl. econ. Ent.* 32, *pt. 3*, pp. 401-403.

Zolotarevsky, B.N. (1929). "Le criquet migrateur (*Locusta migratoria capito* Sauss) a Madagascar," *Ann. Epiphyties, XV, Jul-Augt 1929.*

Zolotarevsky, B. N. 1933. "Contribution a l'etude biologique du criquet migrateur (*Loc. m. capito* Sauss.) dans ses foyers permanents," *Ann. Epiphyties, Paris, XIX, pp. 47-142*, 1933.

Zolotarevsky, B. N. & Murat, M. (1938). "Rapport scientifique sur les recherches de la mission d' Etudes de la Biologie des Acridiens en Mauretanie (A.O.F.) Premier mission Oct. 1935—Mars 1937," *Bull. Soc. D'Hist nat. Afr. Nord. Tome, XXIX* 1938.

Zolotarevsky, B. N. (1939). "Le criquet nomade (*Nomadacris septemfasciata* Serv.) en Afrique Francaise," *Bull. Soc. Hist. Nat. Afr. Nord. XXX. 2. Alger* 1939.

LIST OF PLATES

Text Page

Plate 1.—*High Sand-dunes in the Mallani area* near Bamnor; dunes covered with grass and scattered Acacia trees. Various tall bushes in the fore-ground. The granite hill of Chohtan seen at the back of the dune. November, 1932. 20

Plate 2.—*Pugal Village on top of a sand-dune.*—August 1937. Western Bikaner; an area of undulating sand-dune country ; Khejdi trees (*Prosopis*) fairly common around village. Bushes in the fore-ground mostly Murt (*Panicum turgidum*) and Siniya (*Crotalaria burhia*). . . 20

Plate 3.—*Bagar Area of sandy loam soils in Lasbela State.*—A large belt of sandy loams stretches from the banks of the Porali to the sides of the Mor Range in Lasbela State. These soils were evidently formed of blown silt in the course of ages, and forms a vast area which is suitable for egg laying after heavy rain-fall. The motor track from Karachi to Sonmiani and Bela passes through a large part of this area. The soil and vegetation are somewhat similar to those of the old dune areas of the Desert. 21

Plate 4.—Chart showing track of western disturbances 25

Plate 5.—Chart showing track of Bay depressions 28

Plate 6.—*Desert to the north of Nokh.*—Mostly covered with large bushes of Lana (*Haloxylon salicornicum*); fairly large clumps of Murt (*Panicum turgidum*) were also present——July, 1936 37

Plate 7.—*Open Desert Area near Girasar (Jaisalmer).*—Ground covered with recent growth (after June rain) of Bekkar (*Indigofera cordifolia*) in fore-ground, as well as a few grass clumps of Siwan (*Elionurus*). Fairly good numbers of hoppers were seen here in July 1936 . 37

Plate 8.—*Grass-covered area of the Desert.*—Near Sodakhor (Jaisalmer) November 1932. Grasses mostly Sivan (*Elionurus*) and Murt (*Panicum*). Several adults of *Schistocerca* and a small number of *Locusta* were found in these areas in November 1932 . . 37

Plate 9.—*A rank growth of grass and annuals at Chachro.*—Grass (mostly Bharut.—*Cenchrus catharticus*) and Vishani (*Tephrosia*) and Wekra (*Indigofera cordifolia*) were found rapidly drying up at Chachro in September 1935 37

Plate 10.—*Sardarshahr Locust Outpost.*—Located on the top of a bare dune. The compound fenced with thorn contains the meteorological plot, as well as a small laboratory and a few huts for the accommodation of the workers 48

Plate 11.—*Chachro Locust Outpost.*—On top of a sand-mound, also showing the desert country roundabout. The larger bushes are mostly Calligonum, Calotropis and Capparis. (Febry, 1937.) . . . 48

Plate 12.—*Desert area between Pugal and Rojri.*—August 1937 : Booh plants (*Aerua*) being tapped gently with a stick to note the number of hoppers jumping out of the bushes 52

Plate 13.—*A method of catching solitary locusts.*—A piece of old fishing net is attached to the end of a stick as in photograph. The surveyor keeps as far as possible from the locust and slowly brings the piece of netting nearer and nearer until it hangs vertically over the insect at a distance of about 4 to 6 inches, when it is suddenly dropped flat on the locust. The latter is entangled in the netting and is captured before it can get free 54

Plate 14.—*Pink Locust Swarms at Quetta.*—Pink locusts were found visiting a lucerne field near Quetta in July 1931. The field was badly damaged 59

Plate 15. —*Shashtal Rek near Nasirabad in Kech Valley.*—Photograph (taken in February 1936) of actual site of the Outbreak Centre reported in May—June 1935. Large bands of incipient swarms of hoppers were said to have been seen here 111

ERRATA

Page No.	Line No.		For	Read
4	last line		up to March 31, 19	up to March 31, 1939.
13	7	top	[Uvarov, 1933-34. 1933-36,	[Uvarov, 1933-a, 1933-b,
13	8	top	thorpe, 1937-41, 1937-42	thorpe, 1937-a, 1937-b,
14	40	top	[*Vide P.* 292]	[*vide* P. 218]
15	last line		Raimahal Hills	Rajmahal Hills
16	42	top	theWasht,	the Dasht,
18	17	top	[Predtechensky, 1935, 2]	[Predtechensky 1935-b]
19	25	top	adjoining dunes to	adjoining dunes tend to
19	28	top	(*vide* Fig.)	(*vide* Text-Fig. 1)
20	18	top	the dunes (Fig. 1) are smaller	the dunes (Pl. 2) are smaller
20	6	bottom	soil-exture	soil-texture
21	21	top	maturing chops	maturing crops
21	38	top	scrap	scarp
21	7	bottom	the west cost of the Gulf	the coasts of the Gulf
26	20	bottom	1923-24*..12.17. 3.83	1923-24..2.17 ..3.83
30	15	bottom	1911**..2.50.. 6.09..29·57	1911**..2.50 ..6·09..2·57
32	33	top	Predtechensky [1935, 2]	Predtechensky [1935-b]
34	1	top	*Periplocaaphylla* Decne,	*Periploca aphylla* Decne
34	32	top	Leaflets Caper, *Capparis aphylla* Roth.	Leafless Caper *Capparis aphylla* Roth.
34	9	bottom	Leayyo, *Cressa cretica*	Leyyo, *Cress*[a] *cretica*
37	4	top	*Holoxylom salicornicum*	*Haloxylon salicornicum*
38	17	top	of habitat *Heliotropium*	of habitat: *Heliotropium*
40	8	top	belong to general	belong to genera
41	7	bottom	the Aoughscaled Viper	the Rough-scaled Viper
43	9	top	Blanford [1876--2]	Blanford [1876 -b]
51	19	top	$P = \frac{L}{M \times 22/5280 \times D}$	$P = \frac{L}{M \times 22/5280 \times D}$
			$\frac{L \times 5280}{M \times 22 \times D}$ or	$\frac{L \times 5280}{M \times 22 \times D}$
55	11	top	67S:29T:L G:45 (6):55(7)	67S:29T:4G:: 45(6):55(7)
72	39	top	northerly on northeasterly	northerly or northeasterly
85	18	bottom	68S:T:2G::38 (6):62(7)	68S:30T:2G ::38(6):62 (7).
97	32	top	and breeding commenced	breeding commenced
114	6	bottom	(1935-2, Chap. XXII)	(1935-b, Chap. XXII)
126	16	top	averabe density	average density
136	5	top	of '*Arzu*'	of '*Arzun*'—
137	10	top	OG:O:57(6):	OG: :57(6):
137	13	bottom	a district fall in	a distinct fall in
147	11	top	and some elsewhere	and none elsewhere
150	3	bottom	ratos and forms	ratios and forms
154	32	top	as on locusts were	as no locusts were
154	46	top	their lying-bases	their wing-bases
155	27	top	Gar and Rohtak	Gar and Rotak
160	3	bottom	desccation	desiccation
164	4	top	53S: 45T: 2G: 76(6): 29(7)	53S: 45T: 2G ::76(6):24(7)
164	29	top	(mostly *in capula*)	(mostly in *copula*)
164	12	bottom	by these wings.	by these winds
181	14	top	Harnai Adm.,	Harnai 1 in.,
182	16	top	Bibi	Sibi
182	20	top	Peeni	Pasni
190	19	top	Dash-i-Shah-baz	Dasht-i-Shah-baz
193	12	top	::42(6):53(7)	::42(6):58(7)
207	17	bottom	the place was oviposition	the place of oviposition
210	17	top	(Table 1) (4th column:) 3	34
211	5	bottom	(Table II) (4th column) 6	36
227	13	top	*Capparis aphulla*, ...Casurina,	*Capparis aphylla*,....Casuarina,
227	14	bottom	*Convolwvlus*	*Convolvulus*
227	2	bottom	*hyssopifalia*,	*hyssopifolia*,
233	last line		(*Citruluscolocynthis*),	(*Citrullus colocynthis*),
235	13	top	*khib*	*khip*

Page No.	Line No.	For	Read
239	16 top—	(as iuterstripe).	or interstripe).
239	7 bottom	[1935, No. 11]	[1935-a, No. 11]
240	4 bottom	for tonfining	for confining
242	33 top	sixstages	of six stages
243	5 bottom	(Table XII) V-A....2·81.. nil	V-A....2·81 ..2·50
245	16 top	of the rapid of the body	of the rest of the body
256	29 top	Pasni region in fairly	Pasni region is fairly
256	7 bottom	Shadi Kaur of Pasni.	Shadi Kaur north of Pasni
265	17 top .	*Bharat (Cenchrus*	*Bharut (Cenchrus*
266	3 top .	slumps-*Siwan* or *Murt*	clumps-*Siwan Murt*
266	30 top .	tole of parasites	role of parasites
266	3 bottom	or *Bhinopoma*	*or Rhinopoma*
267	4 top .	Leilell (Sind) has been	(Sind) has been
267	7 top .	*Pyenontidae*	*Pycnonotidae*
268	14 bottom	*Galedoes*	*Galeodes*
282	7 top .	38 *Coressa cretica*	38 *Cressa cretica*
282	29 top .	55 *Pennisotum*	55 *Pennisetum*
282	34 top .	59 *Schismus marginattus*	59 *Schismus marginatus*
283	17 top .	84 *oeni. dactylifera*	84 *Phoenix dactylifera*
283	22 top .	87 *Pleropyrum*	87 *Pteropyrum*
284	7 bottom	Fam. *Captimulgidea*	Fam. *Caprimulgidae*
286	28 top .	*chizodactylus*	*Schizodactylus*
286	last line	*Crocoothemisserviliaeryth raca*	*Crocothemis Crocothemis servilia erythrura*
294	Table 2nd line	(last col.) C/B	H./C."
294	Table 3 from bottom	(13th column) 1·808	1·308
300	25 top .	closed together	close together
309	Footnote	*Patanga japanica*	*Patanga japonica.*
328	8 bottom	(Rao 1936, 1947, I)	(Rao 1936, 1937-a)
360	18 top .	of the data of-occurrence.	of the date of occurrence.
382	16 top .	(data not given)	(date not given)
382	11 bottom	to September 1926".	to September 1928".
397	last line	Sudaon	Budaon
398	1st line	Ninital	Ninital
399	4 bottom	near the boards of	near the borders of
405	1st line	West C.P.) Akolo,	West C.P. (Akola
436	Table of Rainfall	Figures for 'September' have been shown as "1, 3, 5, 12, 2 and 3."	They should read as "1·09 3·04, 5·64, 12·01 2·16 and 3·05" respectively.
445	Table of Rainfall	Figures for 'April' have been shown as "0·5, 3·8, 0·6, 2·2".	They should read as "0·53 3·81, 0·63 and 2·21" respectively.
456	16 bottom	(2) Over-writering was	(2) Over-wintering was
476	29 top .	Brinpura	Erinpura
479	10 top .	*raji* crops	*Ragi crops.*
482	22 bottom	good railfall	good rainfall
483	9 bottom	Cotes [1891]	[Cotes, 1891]
488	4 top .	Sharpur,	Shikarpur.
489	1st line	III. *Sumamer* 1891.	III. *Summer* 1891.
494	18 top .	IV. Autumn EBFT	IV. Autumn 1892.
495	1st line	YEAR 1892	YEAR 1893.
495	2nd line	A. Weather Notes 1892.	A. Weather Notes 1893.
495	3 top .	*Rainfall* 1891-1892	*Rainfall* 1892-1893.
502	25 top .	Rainfall 1854	Rainfall 1895.
504	5 top .	*Rainfall* 1894-95	*Rainfall* 1895-96
510	12 top .	Marwar Tahsil of Bannu.	Marwat Tahsil of Bannu
520	36 top .	of Thar-Parkar through	of Thar-Parkar passed through
521	6 to 26 top .	Table I—*Winter Spring Rainfall* 1899-1900.	Delete the entire column for "May".
524	14 top .	(May) 4·82	(May) 4·62
524	18 top .	(May) 3·08	(May) 2·08
547	25 top .	(Table 1) 1905-06 May.	1905-06 Nov.
550	12 top .	June, though they	June, though they
550	24 top .	ana in Jhalawar	and in Jhalawan
551	23 top	Merwar, Jaipur	Mewar, Jaipur
553	23 top .	south-east to northeast	south-east to north-west

Page No.	Line No.		For	Read
553	28	top	Garauli, etc.	Karauli etc.,
559	12	top	E. S. Cotes	E. C. Cotes.
582	12	bottom	Wadhawan and Badhanpur areas (Jhinjuwade)	Wadhwan and Radhanpur areas (Jhinjuwada.
582	10	bottom	noticed warming	noticed swarming
589	10	top	Were accompanied by	wave accompanied by
589	9	bottom	Surgeon-Major Hendely	Surgeon-Major Hendley
590	27	top	Prinpura	Erinpura
590	28	top	Bikaner.. 6·95	Bikaner ..0·95
593	13	bottom	a swarm—free period.	a swarm-free period
603	23	top	the development of	the production of
606	19	top	Frosk.,	Forsk.,
606	20	top	the cost of Devon	the coast of Devon
607	26	top	(Warangal, 29th October, 1930)	(Warangal 29th September, 1930)
614	16	bottom	years 1869, 1876 and 1889, the new cycles were	years 1900, 1912 and 1940, the first report of the
621	11	top	Hediaj and Yemen	Hedjaj and Yemen
623	26	top	*Acridum*	*Acridium*
627	last line		Doubtless the furnished	Doubtless, the set furnished
628	35	top	the retrating	the retreating
632	5	top	since 1943,	since 1843

STATEMENTS

STATEMENT

Monthly data in regard to various meteorological observations

Months	SCREEN					OPEN AIR		
	Relative humidity (Daily mean with range)	Relative humidity at 9-30 A.M. & 5 P.M. respectively	Temperature (dry bulb daily mean with range) °C	Wet minimum temperature °C	Wet maximum temperature °C	Maximum temperature of coloured bulbs (not in vacuum) in °C		
						white bulb	Black bulb	Grass minimum temp.
December 1937	56% ±12	59%&49%	18·1±7·2	8·4	17·4	20·0	34·8	8·2
January 1938 .	70% ±11	78%&63%	18·0±4·9	10·9	16·6	24·6	31·1	..
February 1938	63% ±16	70%&51%	18·2±6·1	9·5	16·2	25·1	33·5	10·3
March 1938 .	68% ±14	70%&50%	22.3±6·2	18·8	19·4	32·7	39·8	13·8
April 1938 .	71% ±19	75%&60%	25·1±6·1	18·3	23·7	30·6	42·3	17·4
May 1938 .	74% ±14	71%&68%	28·8±5·1	22·2	28·5	41·0	43·7	21·2
June 1938 .	72% ±13	71%&73%	30·0±3·9	25·2	28·9	41·6	43·6	25·2
July 1938 .	75% ±11	77%&68%	28·8±2·9	24·6	26·3	39·8	42·5	25·5
August 1938 .	76% ±10	76%&68%	27·4±3·2	23·3	24·8	37·8	40·3	23·8
September 1938	78% ±15	84%&69%	26·4±4·4	21·3	25·1	37·5	40·2	21·3
October 1938 .	65% ±16	72%&60%	26·5±6·4	17·3	24·4	39·1	42·3	17·3
November 1938	47% ±17	50%&40%	21·6±7·3	11·1	18·8	36·5	40·7	12·2
Average for 12 months	69% ±14	70%&61%	24·2±5·3	17·2	22·5	35·4	30·6	17·8

IX

taken on the Pasni Rekduring a period of 12 months.

Evaporation in 24 hours (in c.c.)			Hours of sunshine per day	WIND			
Height above ground							
4 ft.		4 in.		Total mileage per day	Maximum velocity in miles per day	Prevailing direction	Remarks
In sun	In shade (Screen)	In sun					
11·0	8·5	11·5	8·2	151·2	12	Mostly north (varying) land breeze.	The driest month.
9·5	6·6	9·5	7·7	163·8	14·1	Mostly north (varying)land breeze.	The coldest month.
10·5	8·6	10·6	9·3	167·9	15·8	Always north (varying) breeze in forenoon and sea breeze in afternoon ('*Garich*' on 6 days)	
13·2	9·6	13·3	8·2	210·7	19·9	As above (Severe dust storm on the 20th & 21st)	
12·6	7·5	11·5	10·4	216·7	30·0	As above	
14·9	9·2	17·0	8·8	252·3	21·7	Mostly SWW. No north breeze.	Land breeze stopped. Sea breeze established.
16·6	7·7	14·3	7·4	235·7	21·7	SSW.,SW.,SWW.	
11·6	6·2	11·7	7·0	222·1	18·3	SSW., SWW., E in forenoons of 9 days	
10·1	6·4	12·9	5·3	241·9	19·2	SWW., SSW.	Forenoons mostly cloudy.
11·6	5·9	14·7	8·4	262·7	21·9	Mostly SWW.	Fog and dew on many days.
12·5	7·8	13·9	9·5	201·3	19·1	Mostly N. (varying) in forenoons, sea breeze in afternoons.	Change of weather. Fog and land breeze frequent.
15·2	11·8	14·7	9·8	192·9	13·5	Always N. (varying) in forenoons, sea breeze in afternoons	
12·2	7·9	13·0	8·3	210·7	18·1	..	

STATEMENT

Monthly data in regard to various meteorological observations

Months	Variation of barometric pressure (in inches)	Temperature at 4 in. depth of wet soil in glass oviposition tube (°C)	Sand soil temperature in open (daily with range) in C°		
			Surface		At 2 in. depth
			Horizontal bulb	Vertical bulb	
December 1937 .	20·98 to 30·30	20·1±8·4	21·7±13·7	21·3±11·5	12·7±7·3
January 1938 .	30·08 to 30·37	19·9±6·2	20·2±9·2	18·6±7·9	19·0±6·1
February 1938 .	30·09 to 30·35	20·0±7·4	22·7±12·9	22·0±10·8	20·4±7·8
March 1938 .	20·83 to 30·13	24·3±7·4	29·1±15·5	26·9±11	28·9±9·5
April 1938 . .	20·71 to 30·12	28·4±7·1	32·4±15·5	30·3±11·5	30·3±8·8
May 1938 . .	21·58 to 20·72	32·1±7·0	38·2±15·6	34·2±10·3	34·7±8·8
June 1938 . .	20·45 to 20·70	33·7±6·5	39·2±14·6	33·2±9.0	35.6±5·7
July 1938 . .	29·45 to 29·75	32·9±5·7	37·4±12·5	35·1±3·2	34·4±4·8
August 1938 .	20·52 to 29·75	30·9±5·4	35·3±11·8	33·5±5.9	33·3±4·7
September 1938 .	29·62 to 29·96	29·7±6·0	39·9±13·1	32·5±9·6	33·1±7·1
October 1938 .	20·60 to 30·18	27·9±7·9	31·6±15·5	30·8±12·5	36·5±7·7
November 1938 .	20·00 to 30·30	23·4±8·5	24·5±14·5	25·2±13·0	24·6±7·9
Average for 12 months	..	26·9±7	30·5±13·7	23·8±10·1	28·6±7·2

IX—*contd.*

taken on the Pasni Rek during a period of 12 months.

Mean	Maximum percentage of sand soil moisture during the month at minimum temperature time			Depth at which moist layers were reached (in inches)	Rainfall in inches	Remarks
At 4 in. depth	Surface	At 2 in. depth	At 4 in. depth			
20·0±4·1	..	..	..	24	08·86	The driest month.
16·9±4·4	5·90	7·10	7·18	Soil moisture near surface	1·73	The coldest month.
30·5±5·4	5·00	6·04	8·79	Do.	1·39	
25·9±5·3	1·94	3·1	4·11	3 to 6	Nil	
29·5±5·1	2·81	1·31	1·71	do.	0·09	
33·8±5·8	0·67	0·40	0·62	10	Nil.	Land breeze stopped. Sea breeze established.
35·7±5·1	0·48	0·34	0·38	17	Nil.	
34·6±3·8	2·10	0·50	0·50	18	0·33	
32·8±3·2	0·40	0·36	0·37	22	0·01 Fog precipitation	Forenoons mostly cloudy.
31·9±5·0	2·25	0·40	0·46	25	Nil.	Fog and dew on many days.
29·4±5·2	2·44	0·34	0·39	24	0·05 Fog precipitation	Change of weather. Fog and land breeze frequent.
23·7±3·8	1·87	0·88	0·70	23	0·23	
28·1±4·7					4·70 Total for the year	

STATEMENT X

STATEMENT

Monthly data in regard to various Meteorological Observations taken on the Ambagh

Months	SCREEN			OPEN AIR	EVAPORATION IN 24 HOURS (in c.c.) Height above ground	
	Relative Humidity : Daily mean with range (Percentage)	Relative Humidity at 9 A.M. & 5 P.M. respectively (Percentage)	Air Temperature (dry bulb) Daily mean with range (Centigrade)	Temperature (dry bulb) Daily mean with range (Centigrade)	at 4 ft.	at 4 in.
December 1937	62·5±12·7	57·63	17·29±8·18	17·57±7·65	11·75	7·67
January 1938	63·92±13·92	70·77	17·04±6·91	17·45±7·15	9·25	5·45
February 1938	64·37±19·79	54·72	18·46±7·97	18·81±7·63	12·20	7·02
March 1938	75·20±16·34	75·73	23·47±6·96	23·16±6·56	11·99	7·36
April 1938	77·72±16·65	76·68	26·38±7·16	30·18±10·27	12·03	7·25
May 1938	81·18±12·74	78·83	29·48±4·55	30·61±4·17	11·05	5·49
June 1938	82·89± 9·89	83·82	31·39±2·28	32·81±3·96	10·02	6·05
July 1938	86·62± 6·59	88·87	29·49±2·72	30·43±2·94	7·59	4·87
August 1938	86·55±9·05	86·38	28·04±2·99	28·43±2·94	7·25	4·79
September 1938	86·91±9·20	88·89	27·23±3·50	28·02±3·83	6·14	3·64
October 1938	76·76±14·87	79·84	25·92±7·37	26·58±9·35	8·79	5·68
November 1938	58·44±16·92	58·62	21·14±9·35	22·30±9·31	10·79	8·91
Average for the year	76·09±13·22	74·77	24·61±5·91	25·53±7·15	9·90	6·18

X

Rek during a period of 12 months from December 1937 to November 1938

WIND		Variation of barometric pressure (in inches)	Sand Soil Temperature in open (Daily mean with range), in °C			Maximum Percentage of Sand Soil moisture during the month at minimum temperature time		Rainfall in inches
Maximum Velocity in miles per hour	Prevailing direction		Surface	at 2 in. depth	at 4 in. depth	at 2 in. depth	at 4 in. depth	
19·1	E.N.E. W.S.W.	30·21-30·5	23·05 ±14·01	19·62±7·04	18·95±4·48	0·21	0·22	0·78
15·1	W.S.W.	29·4-30·6	23·71 ±14·0	18·82±6·58	17·96±4·96	3·72	4·08	0·53
17·2	W.S.W.	30·2-30·6	27·6 ±16·9	21·61±7·36	20·72±5·53	4·21	3·33	Nil
30·9	S.W. & W.S.W.	30·1-30·3	33·02 ±17·58	27·94±8·10	27·19±5·67	0·78	0·62	Nil
19·2	S.W.& W.S.W.	30·0-30·3	38·00 ±18·76	32·48±8·81	32·25±7·42	0·22	0·19	Nil
27·5	S.W. & W.S.W.	29·8-30·2	42·28 ±15·74	87·35±7·84	36·51±6·24	0·09	0·15	0·16
25·0	S.W. & W.S.W.	29·7-30·0	43·79 ±14·59	39·13±6·37	38·09±4·83	0·04	0·02	0·04
24·5	S.W. & W.S.W.	29·7-30·0	42·04 ±13·67	36·68±6·07	35·88±4·80	5·05	6·39	0·80
25·5	S.W. & W.S.W.	29·8-30·0	37·89 ±11·76	33·06±4·90	32·77±4·18	7·24	7·50	2·98
24·6	S.W. & W.S.W.	29·9-30·2	38·66 ±13·76	32·74±5·26	32·60±4·81	3·72	3·71	Nil
18·0	W.S.W S.S.W.	30·0-30·5	38·06 ±19·04	30·41±6·58	29·97±5·74	0·71	0·92	Nil
15·9	W. & S.W.	30·1-30·6	31·22 ±18·97	24·53±7·21	23·87±5·78	0·32	0·66	Nil
			34·94 ±15·73	29·53±4·86	28·89±5·37	2·19	2·32	5·29 Total for the year

STATEMENT

Monthly data in regard to various meteorological observations taken at Nokh

Months	SCREEN						Evaporation in 24 hours (in c.c.)	
	Relative humidity (percentage)			Air Temperature °C				
	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	In Sun	In Shade
December 1937	51·0±20·0	100	9	14 ± 9·5	28·6	0·0	10·7	7·4
January 1938	50·0±22·0	98	14	13±9·0	27·7	—1·9	11·6	8·2
February 1938	48·5±20·5	100	12	15·5±9·8	33·5	—1·0	13·4	9·0
March 1938	23·5±16·5	71	9	24·4±10·2	39·4	7·5	24·2	14·9
April 1938	35·0±14·0	77	11	30 ±10·1	45·3	12·2	24·0	16·3
May 1938	48·5±18·5	84	11	35·7±8·1	48·3	23·6	34·3	20·2
June 1938	57·0±19·0	91	25	35·5±6·3	45·5	23·4	32·1	16·5
July 1938	63·5±18·5	100	20	34·1±6·1	46·6	24·0	31·3	15·7

XI

during a period of 12 months from December 1937 to November 1938

Sand soil temperature in open (Daily mean with range) in °C.			Rainfall in inches	WIND		REMARKS
Surface	Highest maximum for the month	Lowest minimum for the month		Prevailing direction	Sand storms	
19·2±14·0	41·0	0·0	0·53	NW,N,NE.	Nil	Bright sun-shine for certain days and bright sun-shine interrupted on others. Temperature low during 2nd fortnight. Some rainon 4 days. Fog on 20th.
18·9±14·4	41·0	—0·5	Nil	NE,NW,N,E	Nil	Mostly bright sunshine.
24·2±18·6	54·0	—0·5	Nil	W,NW,SW, NE,E.	Nil	On the whole sky clear with bright sunshine. Dusty on 14th, 15th. Fog on 6th.
34·4±20·7	61·8	8·0	Nil	W,SW,N, E, NW,S.	Nil	Mostly bright sunshine though dusty on 11th, 14th, 17th, 19th, 21st and 22nd.
41·9±22·7	73·5	12·0	Nil	E,N,S,W, SE,SW,NW.	12th—W	Mostly bright sunshine with occasional clouds causing drizzle on 12th & 24th. Dusty on 5th, 12th, and 21st.
47·2±19·7	74·0	23·5	Nil	W,S,N,SW.	30th—W	Mostly bright sunshine interrupted slightly now and then. Dusty from 12th to 21st & 30th.
45·6±16·0	72·5	25·7	2·07	SE,S,W,N,E, SW,NE.	2nd—E 3rd—SE 7th—SE 8th—SE 9th—NE 11th—S 21st—N 22nd—NE 23rd—N	Clouds on a number of days with rain on 9th, 13th, 25th, 26th. Day dusty on 2nd 3rd, 7th, 8th, 9th, 11th, 15th, 19th to 23rd.
44·5±15·4	67·0	26·5	4·68	S,W,N,E, SW.	8th—S 23rd—S 24th—N 25th—S	Bright sun-shine interrupted with rain from 23rd to 27th.

STATEMENT

Monthly data in regard to various meteorological observations taken at Nokh

Months	SCREEN						Evaporation in 24 hours (in c.c)	
	Relative humidity (percentage)			Air Temperature in °C				
	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	In Sun	In Shade
August 1938	69·0±16·0	98	34	32·4± 5·7	41·5	25·2	22·5	13·6
September 1938	58·0±20·0	91	17	31·4± 7·2	43·0	20·5	23·0	12·9
October 1938	55·0±15·0	90	17	28 ± 9·8	42·7	13·8	20·0	12·8
November 1938	50·5±11·5	79	15	18·9±11·3	34·8	—0·6	14·0	9·5
Average for the year	52 ±17	..	..	26·1± 8·6	..	..	21·8	13·2

XI—*contd.*

during a period of 12 months from December 1937 to November 1938—contd.

Sand soil temperature in open (Daily mean with range) in °C.			Rainfall in inches	WIND		REMARKS
Surface	Highest maximum for the month	Lowest minimum for the month		Prevailing direction	Sand stor	
42·6±15·2	67·0	25·1	0·72	S,E,SW,NE.	26th—E	Cloudy in 2nd fortnight of the month with rain from 25th to 29th. Dusty on 11th and 26th.
42·0± 7·5	67·2	21·0	Nil	W,S,SW, E,SE.	Nil	Mostly bright sunshine. Dusty on 20th and 21st.
36·7±18·5	64·5	14·0	Nil	S,W,N,E,NE SW,SE.	Nil	Mostly bright sunshine. Dusty on 6th
26·6±18·7	53·8	1·0	Nil	E,NE,N,SW, NW,SE,W,S.	Nil	On the whole bright sun-shine without any strong wind.
25·3±16·8	..	..	8·00 Total for the year.	..	..	..

STATEMENT

Monthly Data in regard to various Meteorological Observations taken at Chachro,

Months	SCREEN						Evaporation in 24 hours (in c.c.)	
	Relative Humidity			Air Temperature in °C.				
	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	In Sun	In Shade
December 1937	51·0±19·0	100%	8%	16·3±9·3	30	1·1	14·1	10·0
January 1938	44·0±18·0	100%	13%	15·7±8·5	30	2·9	16·0	12·2
February 1938	43·5±18·5	100%	10%	18·6±9·4	36·6	2·0	19·6	13·8
March 1938	46·5±25·5	100%	8%	26·5±9·7	48	10·6	27·5	17·1
April 1938	43·0±21·0	95%	13%	30·3±10·1	45·2	13·9	31·5	18·4
May 1938	57·0±27·0	95%	13%	33·5±7·9	46·9	23·8	36·6	18·0
June 1938	63·0±22·0	93%	23%	36·8±9·2	42·7	25	26·2	14·4

XII

during a period of 12 months from December 1937 to November 1938

Sand Soil Temperature in open (Daily mean with range) in °C.			Rainfall in inches	WIND		REMARK
Surface	Highest maximum for the month	Lowest minimum for the month		Prevailing direction	Sand storms	
21·5±15·3	48·0	0·7	0·55	N,NW,SW, S,SE,E,NE.	Nil	Bright sun-shine or bright sun-shine interrupted with slight rain clouds on 3 days. Fog on 19th. 20th, 21st & 29th.
21·5∓15·7	45·0	1·2	Nil	W,N,E,NE, SW.	Nil	Strong N. Breeze blowing. Dust on 2nd, cloudy from 8th to 12th, otherwise mostly bright sun-shine. Fog on 27th and 31st.
27·4±19·4	57·2	1·0	Nil	W,N,S,SW, NW,NE.	Nil	On the whole, the sky remained clear with bright sun-shine. Dusty on 13th to 15th. Fog on 10th, 12th, 13th & 23rd.
25·8±20·3	63·8	10·4	Nil	S,SW,N,NE, NW,W,E.	21st-SW (light dust storm)	On the whole, the sky clear with a few clouds appearing here and there. Dusty on 4th 9th, 10th, 11th, 21st. 22nd & 28th. Fog on 6th, 7th, and 21st.
40·5±21·7	68·0	13·0	Nil	S,N,W,E, SW,NW.	6th-SW 21st-S 23rd-SW	As in March 1938—Dusty on 5th, 6th, 18th, 19th, 20th, 21st, 23rd, 24th and 29th.
40·1±14·9	72·0	22·4	0·52	SW,S,W,E.	1st-SW 11th-S 12th-S 13th-SW 14th-SW 29th-S 30th-SW	On the whole, sky clear with a few clouds here and there, but dark clouds with rainfall on 25th & 29th. Dusty on 1st and 3rd, 4th, 5th, 7th, 9th to 15th. 17th to 20th, 29th and 30th.
41·7±14·0	63·9	24·4	0·81	S,E,NE,SE, SW.	7th-E 9th-NE 11th-E 27th-S	Sky for the most part cloudy, rain on 3 days. Dusty on 7th, 9th, 11th, 15th, 16th, 17th, 19th, 22nd, 23rd, 25th, 26th, 27th and 28th.

STATEMENT

July 1938	68·5 18·5	100%	33%	31·4±5·3	41·9	24·1	24·4	12.1
August 1938	74·0±20·0	100%	42%	29·3±4·3	36·1	23·8	18·8	8·9
September 1938	70·5±23·5	98%	28%	29·1±6·6	42·2	20·5	15·9	9·2
October 1938	56·5±26·5	100%	11%	28·4±9·5	42	13·9	21·0	13·1
November 1938	44·5±12·5	100%	9%	21·4±10·3	35·9	2·2	19·1	11·8
Average for the year	55±21	..	..	26·5±8·3	..	..	22·6	13·3

XII—(*contd.*)

39·7 13·1	66·6	24·2	4·35	S,SW.	Nil	Sky cloudy, but rain-fall on 4 days from 19th. Dusty on 5th 11th, 12th, 13th, 16th 17th, 18th and 31st.
36·8±11·1	58·0	24·0	2·14	S,E,SW,SE, NE.	11th SW 26th. NE	On the whole cloudy Rain-fall on 5 days, from 16th. Dusty on 1st, 9th, 10th 11th, 26th.
37·6±14·7	63·5	20·0	Nil	S,E,N,SW, NE.	Nil	Sky cloudy quite often, but no rain. No strong breeze Fog on 26th.
35·8±17·3	63·0	23·7	Nil	W,SW,NE, N,SE,NW	Nil	Cloudy on many days but no rainfall and no strong breeze. Fog on 7th, 15th 19th, 20th 21st and 23rd.
28·4±17·5	51·0	2·0	Nil	W,S,SW, NW,NE,N		On the whole, bright sunshine. Dusty on 8th and 16th. Fog on 13th, 14th and 15th.
34·0±16·2	..	..	8·37 Total for the year.	..	..	..

STATEMENT

Monthly Data in regard to various Meteorological Observations taken at Sardarshahr,

Months	SCREEN						Evaporation in 24 hours (in c.c.)	
	Relative Humidity			Air Temperature °C.				
	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	In Sun	In Shade
December 1937	48·0±21·0	98%	9%	13·3±9	28	0	10·2	8·0
January 1938	51·5±26·5	100%	7%	12·4±7·7	25·1	—0·4	9·8	7·0
February 1938	44·5±26·5	100%	2%	14·6±9·0	31·1	—0·5	15·7	12·1
March 1938	25·0±16·0	72%	0%	24·0±9·4	38·7	8·3	24·3	17·9
April 1938	22·0±13·0	78·%	3%	29·4±9·5	44·4	13·5	29·1	21·6
May 1938	24·0±13·0	51%	3%	36·1±7·7	46·3	22·5	40·6	28·2
June 1938	45·0±18·0	98%	13%	35·0±6·3	45·7	23·3	29·3	20·4
July 1938	47·5±19·5	98%	7%	34·5±6·2	46·5	25·3	28·6	18·8
August 1938	54·6±19·5	93%	24%	34·3±7·7	41·3	24·4	24·6	16·3

XIII

during a period of 12 months from December 1937 to November 1938

Sand Soil temperature in open (Daily mean with range) °C.			Rainfall in inches	WIND		REMARKS
Surface	Highest maximum for the month	Lowest minimum for the month		Prevailing direction	Sand storms	
17·1±14·1	42·2	2·4	0·37	E,N, W,NW.	21st.W	Bright sunshine interrupted with slight rain, on 18th, 19th & 31st, Fog on 15th, 16th & 17th.
16·4±12·4	35·8	—2·0	0·22	NE,NW,W, N,E.	Nil	Sky cloudy now and then; rain on 1st & 31st. Fog on 7th, 26th only.
20·5±16·1	47·2	—2·0	0·02	NW,SW,N, W,S,NE,E.	Nil	Sky cloudy now and then,slight rain on 6th. Dusty sky on 12th, 14th, 16th and 18th. Fog on 1st, 2nd, 3rd, 7th and 8th.
31·5±18·4	56·0	5·0	Nil	E,N,W,S, SW,SE,NE, NW.	18th. SW 28th-S	Mostly bright sun-shine though dusty on 4th, 7th, 9th, 14th, 17th to 22nd, 28th & 29th.
37·8+19·7	64·8	11·5	0·04	N,E,S,NW, SE,SW,NE, W.	7th-SW 12th-SW 24th-W 25h-SW	Mostly bright sun-shine, though dusty on 7th, 12th, 14th, 24th, 25th, Slight rain on 8th only.
46·0±18·4	70·0	20·2	Nil	S,W,E,N,SN, NE.	13th-W 15th-NE	Mostly bright sun-shine on 1st, 2nd, 6th, 9th, 10th, 13th, 20th & 31st.
43·8±14·9	68·0	25·0	0·92	W,S,E,N, SW, SE, NE.	2nd-NW 3rd-NE 8th-N 11th-SE 12th-N 13th-NE 19th-N 24th-NE	Sky cloudy on a number of days. Dusty on 1st, 2nd, 3rd, 5th, 8th, 11th, 12th, 13th, 17th, 19th, 24th, 26th, 27th, and 28th. Rain on 4th, 12th, 13th, 14th, 15th, 25th 26th, and 27th.
41·4±12·9	56·0	25·0	1·39	N,W,E,NW, SW,NE.	1st-N 8th-NE 15th-NW 25th-SW 26th-E 27th-E 28th-NE	Sky cloudy on quite a number of days though dusty on 1st, 4th, 8th, 9th, 13th, 15th, 17th, 20th, 25th to 31st. But rain on 5 days.
41·5±14·7	65·0	24·5	0·59	E,S,W,SE, NE,NW,SW.	14th-E 22nd-E 26th-NE	Mostly sky clear during 1st and cloudy during 2nd fortnight. Dusty from 1st to 6th, 9th, 14th 22nd, & 26th. Rain on 14th, 23rd, 24th, 27th.

STATEMENT

Monthly data in regard to various Meteorological Observations taken at Sardarshah,

Month	SCREEN						Evaporation in 24 hours (in c.c.)	
	Relative Humidity			Air Temperature °C				
	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	Daily mean with range	Highest maximum for the month	Lowest minimum for the month	In Sun	In Shade
September 1938	44·0±19·0	90%	7%	31·6±7·3	43·3	19·4	25·0	15·9
October 1938	31·0±17·0	89%	3%	27·4±9·3	41·3	13·0	22·2	17·0
November 1938	30·5±14·5	60%	6%	18·5±10·1	32·7	1·9	14·9	11·0
Average for the year	39±19	..	..	26·0±8·9	..	..	22·9	16·0

XIII—(*contd.*)

during a period of 12 months from December 1937 to November 1938.

Sand Soil temperature in open (Daily mean with range) C			Rainfall in inches	WIND		REMARKS
Surfaces	Highest maximum for the month	Lowest minimum for the month		Prevailing direction	Sand storms	
25·6±18·8	64·4	19·0	0·55	E,N,W,NE, SW.	24th-NE 25th-NE	Bright sunshine interrupted some times by clouds 0·55. Rain on 25th, days dusty from 24th to 26th.
23·6±16·0	68·0	12·5	0·09	E,W,NE,SW,NW,SE.	5th-NW 6th-NE	On the whole, the month was bright though a few clouds appeared now and then with 0·09 rain on 6th. Day dusty on 5th, 6th, 16th 23rd and 28th.
23·2±16·4	47·2	0·8	Nil	S,W,N,NE, NW, SW.	Nil	On the whole, bright sunshine. Dusty on 28th
23·2±15·9	..	..	4·19 Total for the year	..	..	.. .. ..

STATEMENT—A

An Analysis of Generation Experiments carried out at Pasni, Ambagh and Chachro during 1933—1938

PASNI

Sessions	Dates of occurrence	Sex matu-ra-tion period	Egg period (In	Hop-per period days)	Range of tempera-ture for each per-iod	Dates of occurrence	Sex-matu-ra-tion period	Egg period (In	Hop-per period days)	Raneg of tempera-ture for each per-iod.
	1933					*1934*				
Autumn-Winter	(Final moult 10-9-32) Oviposition 21-11-32 Hatching 24-12-32 Final moult 16-2-33	.. 63	.. .. 33 ..	 54	.. 26·5± 7·3 21·4±10·3 20·6± 6·1	(Final moult 26-9-33) Oviposition 12-11-33 Hatching 13-12-33 Final moult 8-3-34	.. 47	.. .. 32 ..	 85	.. 24·0± 8·2 21·9± 7·9 18·4± 7·6
Spring	Oviposition 28-3-33 Hatching 19-4-33 Final moult 24-5-33	40	.. 22 ..	 35	22·0± 7·5 25·9± 6·0 27·1± 5·9	Oviposition 23-4-34 Hatching 10-5-34 Final moult 19-6-34	46	.. 17 ..	 36	24·1± 8·4 26·9± 8·0 28·5± 6·3
Summer	Oviposition 10-6-33 Hatching 24-6-33 Final moult 28-7-33	17	.. 14 ..	 34	29·5± 5·4 30·6± 5·0 30·3± 4·2	Oviposition 11-7-34 Hatching 25-7-34 Final moult 28-8-34	26	.. 14 ..	 34	29·3± 3·9 28·7± 2·5 27·8± 2·5
Autumn	Oviposition 6-9-33 Hatching 22-9-33 Final moult 11-11-33	40	.. 16 ..	 50	28·1± 4·1 26·6± 5·9 24·0± 8·2	Oviposition 6-10-34 Hatching 30-10-34 Final moult ..	39	.. 24 ..	.. .. ..	25·4± 3·6 24·5± 6·9 21·3± 6·7
	1935					*1936*				
Autumn Winter.	(Final moult prior to January 1935)					(Final moult 18-9-35) Oviposition 14-11-35 (II) 20-11-35 Hatching 22-12-35 Final moult 21-3-36	.. 63	.. .. .. 32 ..	 89	.. 26·8± 7·7 .. 22·3± 7·5 19·5± 5·9

Spring	Oviposition prtor to 9-2-35	Over 40	..	..	17·3±5·8	Oviposition 28-4-36	38	..	..	23·4±5·8
	Hatching 14-3-35	..	Over 35	..	21·1±5·9	Hatching 14-5-36	..	16	..	28·4±5·0
	Final moult 26-4-35	..	..	43	23·6±6·3	Final moult 24-6-36	..	..	41	29·2±4·4
Summer	Oviposition 31-5-35	35	..	..	27·4±6·1	Oviposition 3-8-36	40	..	..	29·2±3·0
	Hatching 15-6-35	..	15	..	29·4±4·9	Hatching 18-8-36	..	15	..	27·6±3·8
	Final moult 25-7-35	..	..	40	29·3±4·0	Final moult 29-9-36	..	..	42	26·9±3·4
Autumn	Oviposition 28-8-35	34	..	..	26·8±3·1	Oviposition 24-11-30	56	..	..	23·3±6·7
	Hatching 14-9-35	..	17	..	26·3±4·4	Hatching ?				
	Final moult 9-11-35	..	..	56	25·4±6·1					
	1937					*1938*				
Autumn Winter	(Final moult prior to December 1936)					(Final moult prior to January 1938)				
Spring	Oviposition 28-2-37	Over 62	..	..	18·4±6·2	Oviposition 21-2-38	Over 52	..	..	18·1±5·5
	Hatching 29-3-37	..	29	..	21·1±6·7	Hatching 18-3-38	..	25	..	20·3±6·1
	Final moult 15-5-37	..	..	47	26·2±6·0	Final moult 7-5-38	..	..	50	23·8±6·1
Summer	Oviposition 8-7-37	54	..	..	28·9±3·5	Oviposition 27-6-38	51	..	..	29·4±4·5
	Hatching 23-7-37	..	15	..	30·0±3·1	Hatching 12-7-38	..	15	..	28·8±2·0
	Final moult 6-9-37	..	..	45	29·2±3·0	Final moult 16-9-38	..	..	67	27·5±3·5
Autumn	Oviposition 6-11-37	61	..	..	25·9±6·8					

STATEMENT—A—*contd.*

An Analysis of Generation Experiments carried out at Pasni, Ambagh and Chachro during 1933—38

AMBAGH

Seasons	Dates of occurrence	Sex matu-ra-tion period	Egg period (In	Hop-per period days)	Range of tempera-ture for each per-iod	Dates of occurrence	Sex matu-ra-tion period	Egg period (In	Hop-per period days)	Range of tempera-ture for each per-iod
	1936							*1937*		
Autumn-Winter	(Final moult 9-10-35)	..	..	..	..	(Final moult 28-10-36)	..	..	..	..
Spring	Oviposition 6-2-36	120	..	—	22·1±8·7	Oviposition 4-3-07	127	..	..	19·1±8·4
	Hatching 15-3 36	..	38	..	20·8±7·1	Hatching 6-4-37		33	..	21·1±8·5
	Final moult 26-4-36	..	..	42	24·2±7·2	Final moult 18-5-37		..	42	27·4±6·0
Summer	Oviposition 25-5-36	29	..	..	29·3±4·5	Oviposition 25-6-37	38	..	..	29·7±4·0
	Hatching 9-6-36	..	15	..	30·1±3·9	Hatching 7-7-37	..	12	..	30·3±3·4
	Final moult 10-7-36	..	..	31	30·4±3·1	Final moult 13-8-37	..	..	37	29·3±3·0
Autumn	Oviposition 31-8-36	52	..	..	29·0±3·0					
	Hatching 16-9-36	..	16	..	27·8±4·2					
	Final moult 28-10-36	..	..	42	27·0±5·0					

AMBAGH—contd.

	1938				
Autumn-Winter	(Final moult prior to 14-1-38)				
Spring	Oviposition 25-3-38 Hatching 11-4-38 Final moult 25-5-38	Over 70	17	 44	19·7±7·3 26·4±7·2 28·0±5·9
Summer	Oviposition 9-6-38 Hatching 31-7-38 Final moult 7-9-38	45	.. 22 ..	 38	30·5±3·0 29·5±2·7 28·0±3·0
Autumn	Oviposition 16-10-38 Hatching 9-11-38	39 ..	24 ..	.. ..	26·6±5·4 23·5±8·4

CHACHRO

	1936				
Autumn-Winter	Nil				
Spring	Nil				
Summer	(Final moult prior to 27th July 1938) Oviposition 11-8-36 Hatching 27-8-36 Final moult 27-9-36	Over 16	16	 31	30·2±5·4 30·2±5·4 30·1±6·3
Autumn	Oviposition 26-10-36 Hatching 21-11-36	.. 29	26 ..	.. ..	28·7±9·3 23·9±7·8

STATEMENT B

Incubation period in relation to sub-soil temperature, with notes on Sex-Ratio and colour of Hatchings

Ref. No.	Oviposition	Emergence	Incubation period (days)	Average temp. at 4 in. depth	Number of hoppers and colour	Sex Ratio	
						Male	Female
				1935			
H23	30-6-35	13-7-35	13	33·5±5·6	39 (green except 1)	29	10
H24	3-7-35	16-7-35	13	30·6±2·8	36 (black except 1)	21	15
H25	5-7-35	20-7-35	15	32·2±4·2	43 (green) & 4 (black)	28	19
H27	13-7-35	27-7-36	14	31·0±3·4	51 (black)	30	21
H28	14-7-36	29-7-35	15	30.75±3·35	28 (black) & 4 (green)	21	15
H29	13-7-35	29-7-35	16	30·9±3·4	56 (green)	35	21
H30	15-7-35	31-7-35	16	30·5±3·4	36 (mixed)	24	12
H33	8-8-35	23-8-35	17	29·5±3·7	52 (black)	37	15
H34	10-8-35	27-8-35	17	29·45±3·95	22 (black)	9	15
H35	10-8-35	27-8-35	17	29.45±3·95	35 (green except 2)	28	27
H37	20-8-35	8-9-35	19	29.2±4·7	35 (green except 1)	19	16
H39	29-8-35	16-9-35	17	29·1±5·1	79 (green)	42	37
H40	29-8-35	16-9-35	18	29·15±5·0	47 (mixed)	31	16
H41	30-8-35	18-9-35	19	29·1±5·0	42 (mixed)	20	22
H42	2-9-35	19-9-35	17	28·9±4·8	45 (mixed) (3 eaten by hoppers)	24	24
H46	4-9-35	23-9-35	19	28·5±4·6	56 (green)	30	26
H47	6-9-35	25-9-35	19	28·2±4·7	62 (green) (3 escaped)	31	28
H48	6-9-35	25-9-35	19	28·2±4·7	43 (mostly black)	28	15
H50	9-9-35	28-9-35	19	27·6±4·6	24 (mixed)	8	16
H56	14-9-35	4-10-35	20	27·1±4·5	49 (mixed)	23	26
H59	16-9-35	6-10-35	20	26·7±4·5	22 (mixed)	9	13
H63	17-9-35	10-10-35	23	26·7±4·5	13 (mixed)	5	8
H67	1-10-35	24-10-35	23	26·3±7·9	46 (mostly green)	27	19
H60	4-10-35	26-10-35	22	26·25±8·25	17 (green)	8	9
H71	6-10-35	31-10-35	25	26·65±7·05	14 (green)	9	5
H72	9-10-35	11-1-35	23	26·55±7·35	29 (green)	17	12

Ref. No.	Oviposition	Emergence	Incubation period (days)	Average temp. at 4 in. depth	Number of hoppers and colour	Sex Ratio	
						Male	Female
H73	16-10-35	8-11-35	23	27·0±5·7	16 (mixed) (1 hopper escaped)	11	4
H74	15-10-35	8-11-35	24	27·0±6·0	14 (green)	10	4
H75	15-10-35	8-11-35	24	27·0±6·0	37 (green)	18	19
H77	16-10-35	10-11-35	25	26·0±6·5	25 (green)	13	12
H78	28-10-35	11-11-35	14	26·3±2·9	15 (black)	7	8
H79	22-10-35	17-11-35	26	26·3±3·6	15 (green)	7	8
H80	23-10-35	17-11-35	25	26·4±3·3	26 (green) (except 4)	17	9
¶H81	23-10-35	18-11-35	26	26·25±3·45	53 (green)	27	26
				1936			
H2	21-11-35	27-12-35	36	21·5±6·4	34 (21 green & 13 black)	17	17
H3	28-4-36	14-5-36	16	28·7±5·3	68 (all black except 2)	45	23
H5	26-6-36	9-7-36	13	32·1±4·2	38 (all green)	23	15
H6	24-6-36	9-7-36	15	32·2±4·1	22 (all green 1 died)	16	6
H7	24-6-36	9-7-36	15	32·2±4·1	25 (all green)	17	8
H9	30-6-36	14-7-36	14	33·1±4·6	52 (40 green, 12 black)	25	27
H11	4-7-36	18-7-36	14	33·1±4·8	31 (mixed, 4 green, 5 black eaten up)	16	15
H12	5-7-36	20-7-36	15	33·4±5·0	24 (19 green, 5 black, 2 eaten up)	11	11
H13	21-7-36	6-8-36	16	32·6±4·0	38 (37 green, 1 escaped)	24	13
H14	3-8-36	18-8-36	15	30·7±3·8	29 (25 black, 4 escaped)	17	8
H15	4-8-36	20-8-36	16	30·5±4.2	30 (all black)	13	17
H16	7-8-36	24-8-36	17	31·0±4·0	26 (mixed)	13	13
H17	8-8-36	24-8-36	16	30·6±4·4	34 (mixed)	16	18
H18	9-8-36	26-8-36	17	30·4±4·3	21 (mixed)	12	9
H21	18-8-36	3-9-36	16	31·0±3·8	17 (mixed)	8	9
H22	21-8-36	7-9-36	17	30·9±3·4	23 (mixed)	10	13

Ref. No.	Oviposition	Emergence	Incubation period (days)	Average temp. at 4 in. depth	Number of hoppers and colour	Sex Ratio	
						Male	Female
				1937			
H4	28-3-37	22-4-37	25	25·9±6·5	31 (22 green, 9 black)	12	19
H5	30-3-37	23-4-37	24	26·0±6·5	43 (41 black, 2 green)	22	21
H7	5-4-37	26-4-37	21	26·6±6·8	107 (17 black, 90 green)	64	43
H8	7-4-37	28-4-37	21	27·0±6·7	14 (all black)	8	6
H9	6-4-37	28-4-37	22	26·9±6·8	49 (all green)	22	27
H10	8-4-37	29-4-37	21	27·1±6·6	38 (all black except 3)	21	17
H11	9-4-37	29-4-37	20	27·1±6·7	143 (mixed)	85	58
H12	5-4-37	29-4-37	24	27·0±6·8	20 (all green)	8	12
H15	22-4-37	10-5-37	18	29·1±6·3	29 (mixed)	15	14
H16	24-4-37	11-5-37	17	29·5±6·8	41 (all black)	24	17
H17	2-5-37	19-5-37	17	30·2±6·0	42 (mixed)	25	17
H27	23-5-37	7-6-37	15	31·5±6·3	39 (all green)	13	26
H28	31-5-37	14-5-37	14	31·4±5·5	38 (all green)	16	22
H31	12-6-37	26-6-37	14	31·3±4·6	40 (mixed)	26	14
H32	12-6-37	27-6-37	15	31·4±4·6	33 (mixed)	22	11
H35	27-6-37	11-7-37	14	32·1±4·8	52 (all green)	16	36
H36	18-7-37	3-8-37	16	31·8±4·6	52 (all green except 3)	30	22
H37	1-8-37	16-8-37	15	31·4±4·7	35 (all green)	21	14
H38	5-8-37	23-8-37	18	30·7±4·5	48 (all green)	21	27

STATEMENT—C

Experiments on the Influence of Quality of Food on the Sex maturity of Schistocerca gregaria

Statement I—Summer Experiments

1935 Summer Season—Pasni

Particulars of Food	Cage No.	Date of final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg layings	Duration of life of female	General Remarks
			Date	Time taken (in days)	Date	Length of period of Sex-maturation (in days)			
A. *Fresh Marrand*	B_9	22-25-V	Not noted	...	27-VI.	33-36	..	..	3 pairs were kept in one cage so that the egg-masses laid by them could not be discriminated.
Do. . .	B_{11}	29-V.	15-VI	16	3-VII.	35	..	..	do.
Do. . .	C_1	30-VI.	19-VII.	19	10-VIII.	40	..	..	Experiment discontinued after first egg laying.
Do. . .	C_6	8-VII.	26-VII.	18	14-VIII.	37	3	66	Died on 12th Sept. 1935
Do. . .	C_9	30-VII.	14-VIII.	15	29-VIII.	30	4	67	Died on 5th Oct. 1935,
Do. . .	C_{17}	9-VIII.	29-VIII.	20	12-IX.	34	1	38	Died on 16th Sept. 1935.
Do. . .	C_{36}	4-IX	18-IX	14	1-X.	27	5	64	Died on 7th Nov. 1935.
Do. . .	C_{37}	5-IX.	24-IX.	19	12-X.	37	3	77	Died on 21st Nov. 1935.
Do. . .	C_{38}	17-IX.	3-X.	16	15-X.	28	7	76	Died on 2nd Dec. 1935. Had fully mature eggs.
Average . .	(9)	.		17·25		33·4	3·8	..	

B.—*Old Marrand* . .	B_{10}	22-25-V	Not noted	..	8-VII.	44-47	..	..	Probably one egg-mass only.
Do. . .	B_{13}	28-30-V	Not noted	..	8-VII.	40-42	..	..	Do.
Do. . .	C_2	1-VII.	22-VII.	21	6-VIII.	36	..	..	Female kept on fresh Marrand for a week before setting up the experiment; discontinued after one egglaying.
Do. . .	C_7	10-VII.	6-VIII.	27	29-VIII.	50	3	76	Died on 24th Sept. 1935.
Do. . .	C_{10}	31-VII.	26-VIII.	26		No Oviposition	..	72	Killed by a centipede on 11th Oct. 1935. Ovaries not dissected out.
Do. . .	C_{10}	9-VIII.	5-IX.	27		No Oviposition	..	70	Died on 18th Oct. 1935. Ovaries half mature.
Average . .	(6)	..	..	25·25	..	43·1	..	..	
C. *Old Marrand wetted*	C_3	2-VII.	26-VII.	24	30-VIII.	59	1	59	Died on 30th Aug. 1935.
Do. . .	C_8	7-VII.	30-VII.	23	30-VIII.	54	2	85	Died on 30th Sept. 1935.
Do. . .	C_{11}	1-VIII.	12-IX.	42	..	..	..	...	Found missing: 16th Sep. 1935.
Do. . .	C_{20}	22-VIII.	9-IX.	18	13-X.	52	1	52	Died on 13th Oct. 1935.
Do. . .	C_{11A}	18-IX	5-X.	17	28-X.	40	3	57	Died on 14th Nov. 1935.
Average . .	(5)	.	..	24·8	..	51·25	..	..	
D. *Old Marrand with moist atmosphere*	B	31-V.	24-VI.	24	15-VII.	45	..	...	3 pairs in one cage, so that egg-laying could not be discriminated.
Do. . .	B_{14}	31-V.	24-VI.	24	17-VII.	47	..	..	Do.
Do. . .	C_{13}	2-VIII.	22-VIII.	20	..	..	..	..	Female flew away on 29th August, 1935.
Do. . .	C_{12} (1)	19-VIII.	18-IX.	26	..	..	..	37	Female flew away on 24th September. 1935.
Do. . .	C_{14}	14-VIII.	9-IX.	26	21-IX.	45	3	58	Killed by centipede : 21st October, 1935.
Do. . .	C_{21}	22-VIII.	9-IX.	18	4-X.	43	1	..	Do.
Average . .	(6)	..	..	23	..	45	..	..	

Particulars of Food	Cage No.	Date of final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg-layings	Duration of life of female	General Remarks
			date	Time taken (in days)	Date	Length of period of Sex-maturation (in days)			
Sowari. . .	C ,,	10-VIII.	27-VIII.	18	4-IX.	25	6	58	Died on 7th October 1935. It had partially mature eggs at time of death; laid eggs every 5th day.
Do. . .	C ,,	18-VIII.	19-VIII.	16	3-IX.	21	2	36	Died on 18th September 1935.
Do. . .	C ,,	18-VIII.	1-IX.	19	2-IX.	20	3	37	Died on 19th September 1935.
Do. . .	C ,,	20-VIII.	5-IX.	14	12-IX.	22	3	42	Died on 2nd October 1935.
Do. . .	C ,,	4-IX.	16I-X	12	30-IX.	26	4	54	Died on 28th October 1935.
Do. . .	C ,,	4-IX.	18-IX.	14	2-X.	28	4	58	Died on 1st November 1935.
Do. . .	C ,,	18-IX.	3-X.	15	14-XI.	57	4	91	Died on 18th December 1935.
Do' . .	C44	19-IX.	3-X.	14	17-X	28	3	56	Died on 15th November 1935. Had fully mature eggs.
Average . . .	(8)	..	..	15·25	..	28·53	3·6	54	..
F. *Kullichk* . .	C	4-VII.	16-VIII.	12	10-VIII.	27	..	..	Experiment discontinued after the 1st egg-laying.
Do. . .	C	6-VIII.	3-IX.	28	22-IX.	47	2	65	Died on the 1th October 1935.

.	C_{16}	6-VIII.	29-VIII.	23	6-IX.	31	2	62	Died on 7th October 1935.
Do. . .	C_{20}	9-VIII.	1-IX.	23	16-IX.	38	2	..	Killed by centipede on 28th September 1935.
Average . . .	(4)	..	..	21·50	..	38·25	2	63	
G. *Balibur*. . .	C_{20}	25-VII.	17-VIII.	23	6-IX.	43	1	73	Died on 6th October 1935.
Do. . .	C_{21}	27-VIII.	22-IX	26	16-IX.	50	1	78	Died on 13th November 1935.
Do. . .	C_{22}	10-VIII.	3-IX.	22	..	..	..	..	Killed by centipede on 13th September 1935.
Do. . .	C_{23}	25-VIII.	22-IX	28	16-X.	52	1	89	Died on 22nd November 1935.
Average . . .	(4)	..	..	24·75	..	48·33	1	80	
H. *Kharzan* . .	C_{17}	5-VI.	Not noted	..	20-VIII.	76	2	91	Died on 4th September 1935; had half developed eggs.
Do. . .	C_{18}	6-VIII.	22-VIII.	16	..	..	..	54	Died on 29th October 1935; had immature ovaries.
Do. . .	C_{19}	7-VIII	25-29 VIII.	22	19-IX.	43	1	60	Died on 6th October 1935.
Do. . .	C_{03}	22-VIII.	24-IX.	33	..	..	..	65	Died on 22nd November 1935.
Average . . .	(4)	..	..	22·66	..	59·50	1·5	67	

Statistical Analysis (S. D.-5·128)

Yellow colour : B C G H D F A E: Oviposition HC G D B F A E (S.D = 8)

Particulars of Food	Cage No.	Date of final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg-layings	Duration of life of female	General Remarks
			Date	Time taken (in days)	Date	Length of period of Sex-maturation (in days)			
1936 Summer Season—Pansi									
A. *Fresh Marrand* .	C_1	29-IV.	9-V.	10	30-V.	31	2	56	Died on 24th June 1936. Had no eggs.
Do. . .	C_8	17-V.	5-VI.	19	28-VI.	42	7	87	Died on 12th August 1936.
Do. . .	C_{12}	20-V.	5-VI.	16	1-VII.	42	2	65	Died on 24th July 1936.
Do. . .	C_{33}	28-V	15-VI	18	12-VII.	45	5	83	Died on 19th August 1936. No eggs.
Do. . .	C_{31}	24-VIII.	9-IX.	16	18-IX.	25	6	56	Died on 19th October 1936.
Average . . .	(5)	..	..	15·80	..	37	4·4	69·4	
B. *Old Marrand* . .	C_6	18-V.	5-VI	18	14-VII.	57	1	58	Died on 15th July 1936.
Do. . .	C_{11}	23-V.	5-VI	13	14-VII.	52	1	54	Died on 16th July 1936.
Do. . .	C_{22}	29-V.	19-VI.	21	..	No egg laying (53 days)	..	53	Died on 21st July 1936.
Average . .	(3)	..	..	17·33	..	54·50	1·0		

C. *Kullichk* . . .	C_8	2-VI	24-VI	22	6-VII	84	2	42	Died on 14th July 1936.
Do. . .	C_{10}	18-V	6-VII	49	..	No egg laying (over 93)	..	93	Died on 19th August 1936. No egg laying, in spite of copulations. Not normal.
Do. . .	C_{27}	24-V	29-VI	36	29-VI	60	2	Over 85	Found missing on 17th August 1936?
Do. . .	C_{24}	29-V	24-VI	26	31-VII	63	1	78	Died on 15th August 1936.
Average	(4)	..	..	33·25	..	61·00	1·6	74·5	
D. *Balibur* . . .	C_4	5-V	28-V	23	24-V	50	2	74	Died on 18th July 1936. No eggs.
Do. . .	C_{33}	18-V	9-VI	22	13-VIII	87	2	111	Died on 6th September 1936. No eggs.
Do. . .	C_{36}	25-V	15-VI	21	4-VII	40	2	64	Died on 28th July 1936. No eggs.
Do. . .	C_{32}	30-V	15-VI	16	..	No egg laying (over 75)	..	75	Died on 13th August 1936.
Average	(4)	..	..	20·50	..	59·00	2	81	
E. *Kharzan* . . .	C_{12}	18-V	15-VI	28	12-VII	55	1	57	Died on 14th July 1936.
Do. . .	C_{21}	3-VI	29-VI	26	20-VII	47	1	70	Died on 12th August 1936.
Average	(2)	..	..	27·00	..	51·00	1	63·5	

Particulars of Food	Cage No.	Date of final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg-layings	Duration of life of female	General Remarks
			Date	Time taken (in days)	Date	Length of period of Sex-maturation (in days)			
F. *Maize*	C_{3}	10-V	23-V	13	8-VI	29	5	70	Died on 19th July 1936.
Do.	C_{11}	30-V	9-VI	10	18-VI	19	6	48	Died on 17th July 1936.
Do.	C_{21}	28-V	9-VI	12	14-VII	47	2	56	Died on 23rd July 1936.
Do.	C_{29}	13-VIII	30-VIII	17	26-IX	44	2	68	Died on 20th October 1936.
Average	(4)	..	..	13·00	..	34·75	3·75	60·5	
G. *Jowari Plant*	C_{34}	5-VI	6-VII	31	7-VII	32	..	..	Flew away on 8th July 1936.
Do.	C_{37}	3-VI	6-VII	33	14-VII	41	4	69	Died on 11th August 1936.
Do.	C_{36}	3-VI	24-VI	21	6-VII	33	5	61	Died on 4th August 1936.
Do.	C_{38}	23-VIII	15-IX	23	30-IX	38	3	53	Died on 15th October 1936.
Average	(4)	..	..	27·00	..	36·00	4	61	
H. *Jowari Seedling*	C_{6}	13-V	23-V	10	19-VI	27	6	76	Died on 28th July 1936.
Do.	C_{14}	20-V	5-VI	10	18-VI	29	6	51	Found missing on 10th July 1936
Do.	C_{27}	28-V	19-VI	22	4-VII	37	4	75	Died on 11th August 1936.

Average	(3)	..	..	16·00	..	34·33	5·3	67·3	

Statistical Analysis : (S.D.-5·97)

Appearance of yellow colour : C E G D B H A F ;

Oviposition : (S.D.-13·77 not significant) C D B E A G F H

1936 Summer Season—Ambagh

A. *Fresh Kharzan*	(6)	10-V	26-V	16	23-VI	44	..	..	Died on 9th July 1936.
Do.	(7)	27-V	16-VI	20	..	..	..	..	Escaped while feeding,
Do.	(8)	19-VI	not noted		14-VII	26	..	..	Discontinued after 1st oviposition.
Average	(3)	..	..	18	..	35	..	..	
B. *Semi-dry Kharzan*	(9)	27-V	..	..	..	..	..	..	Pink colour developed on the body ; ate up the male on 2nd June ; then it also died on 8th June.
C. *Fresh Balibur*	(10)	10-V	20-V	10	23-VII	74	..	..	Discontinued after 1st oviposition.
Do.	(11)	18-VI	not noted		15-VII	27	..	..	
Average		..	..	10	..	50	..	..	

Particulars of Food	Cage No	Date of final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg-laying	Duration of life of female	General Remarks
			Date	Time-taken (in days)	Date	Length of period of Sex-maturation (in days)			
D. *Fresh Mazung*	(12)	10-V.	..	..	..	..	..	..	Body found pink : wings also became pink on 4th June. Died on 4th June.
Do.	(13)	27-V.	..	..	...	..	..	..	Wings found pink on 25th July. Discontinued on 29th June.
E. *Jowari seedling & leaves*	(15)	10-V.	17 V.	7	8-VI.	29	..	..	Died on 29th June. Eggs laid on 23rd June and 28th June.
Do.	(16)	18-V.	Not noted		9-VII.	21	..	..	
Average		..	..	7	.	25		..	

1937 Summer Season—Pasni

A. *Fresh Marrand*	C_1	12-IV.	26 IV.	14	8-V.	26	5	72	Died on 23rd June 1937.
Do. . .	C_6	7-V.	24-V.	17	18-VI.	42	1	?	Female found missing on 7th July 1937.
Do. . .	C_8	8-V.	24-V.	16	20-VI.	43	6	110	Died on 26th August 1937.
Do. . .	C_7	10-V.	27-V.	17	14-VII.	65	3	87	Died on 5th August 1937.
Do. . .	C_{35}	20-VI.	7 VII.	17	12-VIII.	52	1	85	Died on 14th September 1937.
Do. . .	C_{41}	26-VII.	10-VIII.	15	8-IX.	44	?	?	Experiment continued.
Average . .	(6)	..	..	16·00	..	45·33	3·8 (Av. of 4)	89 (Av. of 4)	

B.	*Old Marrand* .	C_3	15-IV.	5-V.	20	9-V.	24	5	71	Died on 25th June 1937.
	Do. . .	C_7	3-VI.	24-VI.	21	30-VII.	57	5	122	Died on 3rd October 1937.
	Do. . .	C_{13}	13-VI.	7-VII.	24	19-VIII.	67	1	88	Died on 9th September 1937.
	Do. . .	C_{18}	10-V.	27-V.	17	..	(Over 102)	0	102	Died on 20th August 1937. No egg-laying.
	Do. . .	C_{26}	10-VII.	28-VII.	18	16-VIII.	37	1	102	Died on 21st October 1937.
	Do. . .	C_{42}	7-VIII.	28-VIII.	21	2-XI .	84	1	..	Alive on 10th November 1937
	Do. . .	C_{47}	22-VIII.	12 IX.	21	..	(Over 82)	..	..	No egg-laying upto 10th November 1937. (Experiment continued.
	Average . .	(7)	..	..	20·20	..	53·80	(2·5 Av. of 5)	97 (Av.) of 5)	
C.	*Jowari Plant* .	C_4	6-V.	31-V.	25	12-VI.	37	3	58	Died on 3rd July 1937.
	Do. . .	C_{19}	7-VI.	28-VII.	51	2-VIII.	56	3	71	Died on 17th August 1937.
	Do. . .	C_{20}	7-VI.	7-VII.	30	21-VII.	44	2	63	Died on 9th August 1937.
	Do. . .	C_{21}	7-VI.	7-VII.	30	16-VII.	39	4	71	Died on 17th August 1937.
	Do. . .	C_{29}	19-VII.	10-VIII.	21	5-IX.	47	3	62	Died on 20th September 1937.
	Do. . .	C_{46}	24-VIII.	19-IX.	26	20-X.	57	..	..	Alive on 10th November 1937.
	Average . .	(6)	..	..	32·17	..	46·67	3 (Av. of 5)	65 (Av. of 5)	
D.	*Jowari seedlings* .	C_5	17-V.	31-V.	14	17-VI.	31	3	(Over 81 days)	Female found missing on 5th August 1937.
	Do. . .	C_{14}	9-V.	24-V.	15	12-VI.	34	6	91	Died on 8th August 1937.

Particulars of Food	Cage No.	Date of final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg-layings	Duration of life of female	General Remarks
			Date	Time taken (in days)	Date	Length of period of Sex-maturation (in days)			
D. *Jowari Seedings—(contd.)*	C_{15}	10-V.	31-V.	21	13-VI.	34	3	67	Died on 16th July 1937.
Do. . .	C_{24}	7-VII.	28-VII.	21	8-VIII.	32	5	61	Died on 6th September 1937.
Do. . .	C_{28}	19-VII.	10-VIII.	22	..	(Over 65)	0	65	Died on 22nd September 1937.
Do. . .	C_{45}	24-VIII.	22-IX.	29	9-X.	46	1	51	Died on 14th October 1937.
Average . .	(6)	..	..	20.33	..	37.40	3 (Av. of 5)	67 (Av. of 5)	
E. *Maize plant* .	C_{9}	8-V.	24-V.	16	29-VII.	82	1	..	Female found missing on 20th August 1937.
Do. . .	C_{10}	8-V.	24-V.	16	20-VI.	43	2	52	Died on 29th June 1937.
Do. . .	C_{16}	18-VI.	7-VII.	19	12-VIII.	55	2	72	Died on 29th August 1937.
Do. . .	C_{27}	12-VII.	28-VII.	16	26-IX.	76	1	90	Died on 10th October 1937.
Average . .	(4)	.	..	16.75	..	64.00	1.7 (Av. of 3)	71 (Av. of 3)	
F. *Maize Seedling*	C_{11}	8-V.	24-V.	16	..	(Over 89)	?	..	Female found missing on 5th August 1937.
Do. . .	$C_{11}A$	4-VIII.	12-IX.	39	..	(Over 65)	0	75	Died on 18th October 1937.
Do. . .	C_{12}	8-V.	24-V.	16	..	(Over 112)	0	122	Died on 28th August 1937.
Do. . .	C_{21}	9-VII.	11-X.	43	..	(Over 73)	?	..	No egg-laying up to 10th November 1937 (Experiment discontinued)

	Do. . .	C_{42}	8-VIII.	12-IX.	34	..	(Over 63)	0	63	Died on 11th October 1937.
	Do. . .	C_{43}	6-VIII.	22-IX.	47	6-XI.	88	1	..	Alive on 10th November 1937.
	Do. . .	C_{44}	6-VIII.	28-VIII.	22	3-X.	59	4	..	Alive on 10th November 1937.
	Average	(7)	..	..	31.00	..	73·50	2·5	86(Av. of 3)	
G	*Mixed Food* .	C_{30}	19-VII.	5-VIII.	17	19-VII.	31	3	92	Died on 19th October 1937.
	Do. . .	C_{32}	12-VIII.	12-IX.	31	..	(Over 90)	?	..	No egg-laying up to 10th November 1937 (Experiment discontinued).
	Do. . .	C_{33}	20-VII.	10-VIII.	21	22-IX.	64	1(?)	?	Found missing on 5th October 1937.
	Do. . .	C_{34}	20-VII.	5-VIII.	16	17-IX.	59	1(?)	..	Alive on 10th November 1937.
	Do. . .	C_{35}	24-VIII.	4-X.	41	..	(Over 78)	(?)	..	No egg-laying up to 10th November 1937(Experiment discontinued).
	Do. . .	C_{36}	23-VII.	10-VIII.	18	26-IX.	65	1	104	Died on 4th November 1937.
	Do. . .	C_{38}	26-VII.	10-VIII.	15	29-IX.	65	2	90	Died on 24th October 1937.
	Do. . .	C_{39}	26-VII.	10-VIII.	15	26-IX.	62	1	67	Died on 1st October 1937.
	Average . .	(8)	..	..	21·75	..	57·67	1·8 (Av. of 4)	87·5 (Av. of 4)	

Statistical Analysis : *Yellow colour :* Oviposition

C F G D B E A : (S. D.-8·003 significant) FE G B C A D : (S. D.-14·82 High : not significant)

Particulars of Food	Cage No.	Date of final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg-layings	Duration of life of female	General Remarks
			Date	Time taken (in days)	Date	Length of period of Sex-maturation (in days).			
1937 Summer Season—Ambagh									
A. *Tender Kharzan* .	17g	14-V.	27-V.	13	27-VI.	44	4	89	Died on 11th August 1937.
Do. . .	17h	2-VIII.	14-VIII.	12	25-VIII.	23	4	82	Died on 23rd October 1937.
Average . . .	..	..	..	12·5	..	33·5	4	85·5	
B. *Comparatively Old Kharzan.*	18b	16-V.	29-V.	13	22-VII.	67	3	143	Died on 6th October 1937.
Average . . .	..	..	..	13	..	67	..	..	
C. *Fresh Balibur* . .	11c	20-V.	7-VI.	18	7-VII.	48	3	122	Found dead on 19th September 1937.
Do. . . .	11d	5-VIII.	18-VIII.	13	1-IX.	27	5	91	Found dead on 4th November 1937.
Average . . .	..	..	..	15·5	..	37·5	4	85·5	
D. *Jowari etc.* . .	16d	4-V.	22-V.	18	5-VI.	32	1	59	Found dead on 2nd July 1937.
Do. . . .	16f	5-VIII.	25-VIII.	18	4-IX.	30	3		Under observation.

Average . . .	..	..	..	18	..	31	2	?	
E. *Fresh Marrand*.. .	20c	18-V.	31-V.	13	4-VII.	47	1	53	Found dead on 10th July 1937.
Do. . . .	20d	3-VIII.	16-VIII.	13	30-VIII.	27	5	115	Found dead on 26th November 1937.
Average . . .	..	..	..	13	..	37	3	84	
F. *Cabbage leaves*. . .	10a	2-IV.	10-IV.	8	30-IV.	28	6	94	Found dead on 5th July 1937. 456 hoppers hatched.
Do. . . .	10b	16-V.	25-V.	9	6-VI.	21	6	49	Found dead on 4th July 1937. 307 hoppers hatched.
Average . . .	..	..	..	8·5	..	24·5	6	72	
G. *Fresh Bosiri* (*Indigofera cordifolia*.)	22a	17-VIII.	24-VIII.	7	Not noted. Presumably about 23-IX	30	1	50	Found dead on 6th October 1937.
Do. . . .	22b	20-VIII.	3-IX.	14	..	..	..	..	Discontinued on 17th November 1937.
Do. . . .	22c	24-VIII.	13-IX.	20	5-X.	42	1	..	Discontinued on 17th November 1937.
Do. . . .	22d	24-VIII.	22-IX.	29	4-X.	19	1	46	Found dead on 9th October 1937.
Average	..	..	..	17·5	..	37	1	42	

Particulars of Food	Cage No.	Date of final moult	First appearance of yelow colour in wings		First Oviposition		Number of egg-layings	Duration of life of female	General Remarks
			Date	Time taken (in days)	Date	Length of period of Sex-maturation (in days).			
H. *Fresh Maikh.* (*Tribulus terrestris*)	23a	4-IX.	14-IX.	0	..	..	..	32	Found dead on 6th October 1937.
Do. . . .	23b	12-IX.	14-IX.	12	18-X.	36	4	..	Discontinued on 17th November 1937.
Average	..	..	..	11	..	36·00	2	..	

Statement—II Autumn—Winter Experiments

1935-36 Autumn and Winter Season—Pasni

A. *Fresh Marrand* . .	C48	14-X-35	29-X-35	15	6-XII-35	53	1	80	Died 7th January 1936. Had half-mature eggs.
	C52	1-X-35	20-X-35	19	6-XII-35	66	3	121	Female died on 30th January 1936.
	C54	16-X-35	15-XI-35	30	No egglaying	(over 75)	..	(Over 75)	Female found missing on 30th December 1935.
Average	(3)	..	..	2·33	..	59·5	..	Over 79·8	

B. *Old Marrand* . .	C39	18·9·35	12·10·35	24	No egglaying.	Over 86	..	86	Female died on 13th December 1935. Had mature eggs.
	C55	9·10·35	2·11·35	24	Do.	Over 94	..	94	Female died on 11th January 1936.
Average . . .	(2)	..	..	24	..	Over 90	..	90	
C. *Old Marrand* (*Wetted*). . .	C40	19·9·35	2·11·35	43	23·11·35	65	1	83	Female died on 11th December 1935.
Average . . .	(1)	..	..	43	..	65	..	70	
D. *Old Marrand* (*with moist atmosphere*). . .	C1 A	25·9·35	12·10·35	17	3·12·35	69	1	90 Over	Died on 24th December. 1935.
	C13	12·9·35	3·10·35	21	4·11·35	53	2	92	Found missing on 13th December 1935.
	C50	25·9·35	20·10·35	25	No egglaying	Over 121	..	121	Died on 24th January 1936. No egglaying.
Average . . .	(3)	..	..	21	..	61	..	Over 10	
E. *Jowari*.	C47	23·9·35	9·10·35	16	2·12·35	70	2	106	Died on 7th January 1936. Had fully mature eggs.
	C51	29·9·35	9·10·35	10	21·11·35	53	3	90	Died on 28th December 1935. Had fully mature eggs.
	C56	9·10·35	24·10·35	15	1·12·35	53	1	?	Female found missing on 11th January 1936.

Particulars of Food	Cage No.	Date of final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg-layings	Duration of life of female	General Remarks
			Date	Time taken (in days)	Date	Length of period of Sex-maturation (in days)			
Average . . .	(3)	..	..	13·67	..	58·67	..	51·3	
F. *Kullichk.* . . .	C42	17·9·35	24·11·35	68	No egg-laying	Over 102	..	102	Died on 28th December 1935. Had half mature eggs.
	C57	10·10·35	..	..	Do.	Over 98	..	98	Died on 16th Jan. 36. Wings still colourless. No egg laid.
Average . . .	(2)	..	..	68	..	Over 100	..	100	
G. *Balibur* . . .	C46	19·9·35	20·10·35	31	4·12·35	76	2	114	Died on 11th January 1936.
	C53	3·10·35	24·11·35	52	12·2·35	132	2	151	Female died on 2nd March 1936.
Average . . .	(2)	..	..	41·5	..	104	..	132·5	
H. *Kharzan* . . .	C54	19·9·35	2·11·35	44	No egg-laying	Over 78	.	78	Died on 6th December 1935. Had half mature eggs.
	C49	10·10·35	5·11·35	26	21·12·35	72	1	89	Female died on 7th January 1936.

Average . . .	(2)	..	..	35	..	Over 75	..	88·5	

1936-37 Autumn Winter Season—Ambagh

A. *Tender Kharzan.* .	17a	24·9·36	15·10·36	21	27·12·36	94	1	103	
Do.	17b	25·4·27	28·2·37	34	9·5·37	104	3	147	
	17c	16·2·37	12·3·37	24	24·4·37	66	5	120	
	17d	18·2·37	12·3·37	22	30·3·37	40	3	89	
Average . . .	(4)	..	..	25·25	..	76	3	115	
B. *Comparatively Old Kharzan.*	18a	24·9·36	12·10·36	16	2·11·36	39	1	53	Died on 16-11-36.
Average . .	(1)	..	.	16	..	39	1	53	
C. *Fresh Balibur* (*Aertia jacanica*)	11(a)	24-IX-36	27-X-36	33	No Oviposition	.	..	306	Died on 27th July 1937.
Do. . . .	11(b)	24-I-37	28-II-37	35	5-V-37	101	1	110	Died on 14th May 1937.
Average. . . .	(2)	..	..	34	..	..	..	208	

Particulars of Food	Cage No.	Date of Final moult	First appearance of yellow colour in wings		First Oviposition		Number of egg-layings	Duration of life of female	General Remarks
			Date	Time taken (in days)	Date	Length of period of Sex-maturation (in days)			
D. *Fresh Mazoung* . .	19*a*	24-IX-36	26-I-37	155	No Oviposition .		..	290	Died on 11th July 1937.
	19*b*	24-I-37	16-IV-37	82	14-V-37	110	1	153	Died on 26th June 1937.
Average	(2)	..	.	118	..	..	..	222	..
E. *Jowari leaves and seedlings.*	16*a*	24-IX-36 (Yellow colour developed 2nd egglaying).	..	.. after	I-37	104	4	190	Died on 2nd April 1937.
..	16*b*	27-I-37	4-III-37	36	9-III-37	41	6	103	Died on 10th May 1937.
Average	(2	..	..	36	..	72	5	149	..
F. *Fresh Marrand* . .	20*a*	24-IX-36	19-X-36	25	19-I-37	117	4	243	Died on 25th May 1937.
	20*b*	26-I-37	19-II-37	24	8-III-37	41	4	..	Found missing on 26th April 1937.
Average.	(2)	..	..	24·5	..	79	4	..	

STATEMENT E

Duration of the Hopper Period as affected by different Food Plants

S. No.	Food Plant	Type of life history	Rearings in the Hotter Months: Total duration (in days)	Number of Rearings	Average duration (in days) 5—instar type	6—instar type	Type of life history	Rearings in the Cooler Months: Total duration (in days)	Number of Rearings	Average duration (in days) 5—instar type	6—instar type
						A M B A G H					
			Summer 1936						*Autumn-Winter 1936-37*		
1.	*Tender Kharzan*	5-ins.	154	4	38·5		5-ins.	2172	34	63·9	
		6-ins.	56	1		56	6-ins.	1008	14		72
			Summer 1937						*Autumn-Winter 1937-38*		
		5-ins.	526	13	40·5		5-ins.	..	..	..	
		6-ins.	387	8		48	6-ins.	316	4	..	79
			Summer 1938							*Spring 1938*	
		5-ins.	41	1	41		5 ins.	48	1	48	
		6-ins.	180	4		45	6-ins.	496	9		55
Average duration		5-ins.	721	18	40		5-ins.	2220	35	63·4	
		6-ins.	623	13		48	6-ins.	1820	27		67
				Summer 1936						*Autumn-Winter 1936-37*	
2.	*Old Kharzan*	5-ins.	169	4	42		5 ins.	143	2	71·5	
		6-ns.	57	1		57	6-ins.	227	3		78

3.	*Marrand Shoots*	*Summer 1936*							*Autumn-Winter-1936-37*			
		5-ins.	..	..	..	..	5-ins.	1345		21	64	58·5
		6-ins.	..	..	..	..	6-ins.		117	2		
		Summer 1937							*Spring 1937*			
		5-ins.	164	4	40·2		5-ins.	198		4	49·5	
		6-ins.	183	3		61·3	6-ins.		186	*Autumn-Winter-1937-38* 2		93
			Summer 1938									
		5-ins	79	2	39·5							
		6-ins.	..	..		..						
Average duration		5-ins.	240	6	40		5-ins.	1543		25	61·7	
		6-ins.	184	3		61·3	6-ins.		303	4		76·7
4.	*Jowari seedlings*		*Summer 1936*						*Autumn-Winter 1936-37*			
		5-ins.	210	6	39·5		6-ins.		470	9		52·2
		6-ins.	..	..		..				*Spring 1937*		
							5-ins.		793	15	53·2	
			Summer 1937							*Autumn-Winter-1937-38*		
		5-ins.	473	13	36·4		5-ins.	149		3	49·7	
		6-ins.	379	9		42·1	6-ins.		194	3		64·7
			Summer 1938									
		6-ins.	204	4	..	51						

	Average duration	5-ins. 6-ins.	683 593	19 13	3·59	44·8	5-ins. 6-ins.	1412 194	27 3	52·3	64.7
		Summer 1936							*Autumn-Winter 1936-1937*		
5	*Balibur*	5-ins. 6-ins.	137	3	45·6	..	5-ins. 6-ins.	68 421	1 5	68	84·2
	Average duration	5-ins. 6-ins.	137	3	45·6	..	5-ins. 6-ins.	68 421	1 5	68	84·2
6	*Masoung Shoots*	5-ins. 5-ins.	.. ..	.. ..	..	..	5-ins. 6-ins.	369 96	4 1	92·2	98
		Summer 1937							*Spring 1937*		
7	*Kohl, Rabi Cabbage*	5-ins. 6-ins.	125 ..	4 ..	31	..	5-ins. 6-ins.	287 ..	6 ..	48	..
8	Bosiri (*Indigofera cordifolia*)	5-ins. 6-ins.	143 80	4 2	36	40	5-ins. 6-ins.	..	..	..	..
		Summer 1937							*Autumn-Winter 1937-1938*		
9	*Maikh* (*Tribulus terrestris*)	5-ins. 6-ins.	147 ..	4 ..	37	..	5-ins. 6-ins.	.. 511	.. 6	.. ..	85·2 ..
									Autumn 1938		
							6-ins.	111	2	..	55·5
	Average duration	5-ins.	147	4	37	..	6-ins.	622	8	..	77·7

S.No.	Food Plant	Type of life history	Rearings in the Hotter Months				Type of life history	Rearings in the Cooler Months			
			Total duration (in days)	Number of Rearings	Average duration (in days)			Total duration (in days)	Number of Rearings	Average duration (in days)	
					5-instar type	6-instar type				5-instar type	6-instar type
10	*Palak* . .		*Summer* 1937	..	..	..	5-ins. 6-ins.	109 266	*Autumn* 1937 1 2	109 ..	.. 133
II	*Ispephul* (*Convolvulus*)	5-ins.	*Summer* 1938 155	4	38·7	..	5-ins.	155	4	*Spring* 1938 38·7	..
	Dranna (*Crotalaria burhia*)	5-ins. 6-ins.	*Summer* 1938 89 ..	2 ..	44·5	..	5-ins. 6-ins.	136	*Spring* 1938 .. 3	.. ..	.. 45·2
						PASNI					
I	*Fresh Marrand*	5-ins. 6-ins.	*Summer* 1936	19 7	..	52·5	..	..	..	..	..
		5-ins. 6-ins.	*Summer* 1937	18 2	41	45·5	..	..	..	..	..
	Average	5-ins. 6-ins.	.. ..	28 9	42·8	50·9	..	..	..	..	..

			Summer 1936								
2	*Old Marrand*	5-ins.	..	..	52		..	..	..	..	..
		6-ins.	..	..		56					
			Summer 1936								
3	*Kullichk*	5-ins.	..	..	..		..	..	..	..	
		6,ins.		1		81					..
			Summer 1936								
	Maize	5-ins.		1	52						
		6-ins.		1		63					
			Summer 1937								
		5-ins.		2	60						
		6-ins.		2		78·5					
	Average duration	5-ins.		3	57						
		6-ins.		3		73					
			Summer 1937								
5	*Maize Seedlings*	5-ins.		1	44						
		6-ins.		2		73·5					
			Summer 1937								
6	*Jowari*	5-ins.									
		6-ins.		3		67					
			Summer 1937								
7	*Jowari Seedlings*	5-ins.									
		6-ins.		4		49					
						KARACHI					
			Summer 1937						*Autumn 1937*		
1	*Cabbage*	5-ins.		1	39		5-ins.				
		6-ins.		7		49·5	6-ins.		3		101
2	*'Palak'*	5-ins		10			5-ins.		8	58	
		6-ins.		3	45·2		6-ins		2		68.5

STATEMENT

Showing the correlation of the number of eye stripes in the compound eyes

(Dr. S. Mukerji,

Series kept in Sunshine : Food : Cabbage.

S. No.	Date of Hatching	Number of stripes in I stage		Date of 1st moult	Number of stripes in II stage		Date of 2nd moult	Number of stripes in III stage		Date of 3rd moult	Number of stripes in extra III stage	
		Early half	Late half		Early half	Late half		Early half	Late half		Early half	Late half
1	Prior to 36—viii	1	2	13.ix.36	2	3	18.ix.36	3	4	26.ix 36	4	5
2	Prior to 4—viii	1	2	12.viii.	2	3	24.viii.	3	4	30.viii	4	5
3	Prior to 2—viii	1	2	24.viii.	2	3	2.ix.	3	4	9.ix	4	5
4	Prior to 15—vii	1	2	20.vii.	2	3	28.vii.	3	4	29.viii.		
5	Prior to 1—viii	1	2	6.viii.	2	3	27.viii.	3	4	5.ix.	4	5
6	Prior to 1—viii	1	2	6.viii.	2	3	25.viii.	3	4	3.ix.	4	5
7	Prior to 30—vii	1	2	6.viii.	2	3	4.ix.	3	4	19.ix.	4	5
8	Prior to 14—viii	1	1	24.viii.	2	3	30.viii.	3	4	8.ix.	4	5
9	6-I-37	1	2	25.i.37	2	3	9.ii.37	3	4	22.ii.37	4	5
10	6-i-37	1	2	26.i.37	2	3	11.ii.37	3	4	24.ii.37	4	5
11	6-i-37	1	2	29.i.	2	3	15.ii.	3	4	2.iii.	4	5
12	9-iv	1	2	17.iv.		3	24.iv.	3	4	30.iv.	4	5
13	9-iv	1	2	17.iv.	2	3	24.iv.	3	4	30.iv.	4	5
14	6-iv	1	2	13.iv.	2	3	21.iv.	3	4	27.iv.	4	5
15	9-iv	1	2	19.iv.	2	3	26.iv.	3	4	3.v.	4	5
16	6-iv	1	2	16.iv.	2	3	24.iv.	3	4	30.iv.	4	5
17	9-iv	1	2	17.iv.	2	3	24.iv.	3	4	30.iv	4	5
18	9-iv	1	2	19.iv.	2	3	28.v.	3	4	5.v.	4	5
19	17-v	1	2	21.v.	2	3	28.iv.	8	4	26.vi.	4	5

H—I

with the number of larval instars in the life-cycle of Schistocerca gregaria *Forsk. Karachi*)

[*Parents with 6-and 7-Eye-stripes*]

Date of Extra 3rd Moult	Number of stripes in IV stage		Date of 4th moult	Number of stripes in V stage		Date of 5th moult	Number of stripes in adult	Hoppes period in days	Sex	Remarks
	Early half	Late half		Early half	Late half					
6.x.36	5	6	18.x.36	6	7	3.ix.36	7		Female	
7.ix.	5	6	18 ix.	6	7	5.x.	7		Female	
18.ix.	5	6	30.ix	6	7	16.x	7		Female	
			12.ix	4	5		5		Male	Became Adult on 12. ix. 5 Eye-stripe; Wings crumpled.
14.ix.	5	6	25.ix.	6	7	14.x.	7		Male	
14.ix.	5	6	25.ix.	6	7	9.x.	7		Male	
			26.ix	5	6	5.x.	6		Male	
14.ix.	5	6	25.ix.	6		12.x.	7		Female	
8.iii.37	5	6	24.iii.37	6	7	12.iv.37	7	96	Male	
12.iii.37	5	6	29.iii.37	6	7	19.iv.37	7	103	Female	
16.iii.	5	6	2.iv.	6	7	21.iv.	7	105	Female	
7.v.	5	6	14.iv.	6	7	26.v.	7	47	Female	
7.v.	5	6	14.v.	6	7	28.v.	7	46	Male	
7.v.	5	6	14.v.	6	7	26.v.	7	50	Female	
10.v.	5	6	17.v.	6	7	28.v.	7	49	Male	
7.v.	5	6	15.v.	6	7	28.v.	7	52	Male	
7.v.	5	6	15.v.	6	7	27.v.	7	48	Female	
13.v.	5	6	21.v.	6	7	31.v.	7	52	Female	
			10.vi.	5	6	25.vi.	6	39	Female	Bred crowded with 6 hoppers.

STATEMENT

S. No.	Date of Hatching	Number of stripes in Ist stage		Date of 1st moult	Number of stripes in II stage		Date of 2nd moult	Number of stripes in III stage		Date of 3rd moult	Number of stripes in extra III stage	
		Early half	Late half		Early half	Late half		Early half	Late half		Early half	Late half
Series kept in Sunshine; Food "Palak"												'Isolated' versus
1	7-vi-37	1	2	12-vi-37	2	3	18-vi-37	3	4	23-vi-37	4	5
2	7-vi	1	2	14-vi	2	3	22-vi	3	4	29-vi	4	5
3	30-vi	1	2	5-vii	2	3	14-vii	3	4	21-vii	4	5
4	18-vi	1	2	24-vi	2	3	30-vi	3	4	7-vii	4	5
5	25-vi	1	2	2-vii	2	3	9-vii	3	4	15-vii	4	5
6	30-vi	1	2	9-vii	2	3	19-vii	3	4	28-vii	4	5
7	5-vii	1	2	11-vii	2	3	19-vii	3	4	26-vii	4	5
8	5-vii	1	2	11-vii	2	3	19-vii	3	4	26-vii	4	5
9	5-vii	1	2	11-vii	2	3	19-vii	3	4	26-vii	4	5
10	18-vi	1	2	25-vi	2	3	2-vii	3	4	10-vii	4	5
11	25-vi	1	2	5-vii	2	3	14-vii	3	4	20-vii	4	5
12	18-vi	1	2	25-vi	2	3	30-vi	3	4	7-vii	4	5
13	28-vi	1	2	5-vii	2	3	19-vii	3	4	28-vii	4	5
Series kept in Sunshine; Food "Palak"												
1	4-ix-37	1	2	19-ix-37	2	3	23-ix-37	3	4	5-x-37	4	5
2	1-ix-37	1	2	8-ix-37	2	3	16-ix-37	3	4	23-ix-37	4	5
3	1-ix	1	2	9-ix	2	3	16-ix	3	4	25-ix	4	5
4	1-ix	1	2	9-ix	2	3	23-ix	3	4	7-x	4	5
5	1-ix	1	2	10-ix	2	3	20-ix	3	4	25-ix	4	5
6	1-ix	1	2	8-ix	2	3	20-ix	3	4	29-ix	4	5
7	1-ix	1	2	9-ix	2	3	16-ix	3	4	27-ix	4	5
8	1-ix	1	2	6-ix	2	3	18-ix	3	4	1-x	4	5
9	1-ix	1	2	8-ix	2	3	20-ix	3	4	1-x	4	5
10	25-ix	1	2	1-ix	2	3	18-x	3	4	5-xi	4	5

H—I—(*contd.*)

Date of Extra 3rd moult	Number of stripes in IV stage		Date of 4th moult	Number of stripes in V stage		Date of 5th moult	Number of stripes in adult	Hopper period in days	Sex	Remarks
	Early half	Late half		Early half	Late half					
	'Partly Crowded' rearing							(*Parents of 6-7 Eye stripes*)		
			29.vi.	5	6	12.vii.	6	35	Male	Bred isolated
			6.vii.	5	6	21.vii.	6	44	Female	—Do—
			2.viii.	5	6	18.viii.	6	49	Female	Bred under partly crowded condition.
			16.vii.	5	6	28 vii.	6	49	Female	—Do—
			24.vii.	5	6	9.viii.	6	45	Male	—Do—
7.viii.	5	8	18.viii.	6	7	28.viii.	7	59	Female	Bred isolated.
			4.viii.	5	6	23.viii.	6	49	Female	Bred under partly crowded condition.
3 viii.	5	8	16.viii.	6	7	24.viii.	7	50	Male	Bred isolated
			4.viii.	5	6	21.viii.	6	47	Male	Bred under partl crowded condition.
			17.vii.	5	6	2.viii.	6	45	Male	—Do—
30.vii.	5	8	18 viii.	5	7	21.viii.	7	57	Male	Bred isolated.
			15.vii.	5	6	28.vii	6	40	Female	Bred under partly crowded condition.
			6.viii.	5	6	25.viii.	6	58	Male	Bred isolated.
								(*Parents 6-7 Eye-stripes*)		
			15.x.37	5	6	2.xi.37	6	59	Male	
			5.x.37	5	6	22.x.37	6	51	Female	
			5.x.	5	6	25.x.	6	54	Male	
			13.x.	5	6	2.xi.	6	62	Male	
			11.x.	5	6	1.xi.	6	61	Female	
			9.x.	5	6	26.x.	6	55	Male	
			9.x.	5	6	21.x.	6	50	Female	
			18.x.	6	7	8.xi.	7	68	Female	
3.x.37	5	8	20.x.	6	7	9.xi.	7	69	Female	
3.x.37	5	8	19.xi.	5	6	5.xii.	6	71	Male	

STATEMENT

S. No.	Date of Hatching	Number of stripes in 1st stage		Date of 1st moult	Number of stripes in II stage		Date of 2nd moult	Number of stripes in III stage		Date of 3rd moult	Number of stripes in extra III stage	
Series kept in Sunshine; Food : Cabbage.												
1	Prior to 27.x.37	1	2	7.xi.36	2	3	19.xi.36	3	4	1.xii.36	4	5
2	Prior to 27.x.36	1	2	7.xi.36	2	3	16.xi.36	3	4	25.xi.36	4	5
3	Prior to 17.x.36	1	2	11.xi.36	2	3	19.xi.36	3	4	28.xi.36	4	5
Series kept in Shade ; Food : Cabbage.												
1	Prior to 6.xi.36	1	2	14.xi.36	2	3	20.xi.36	3	4	1.xii.36	4	5
2	Prior to 7.xi.36	1	2	14.xi.	2	3	23.xi.	3	4	30.xi.36	4	5
3	Prior to 30.xi.36	1	2	5.xii	2	3	18.xii.	3	4	7.i.37	4	5
4	Prior to 4.xi.36	1	2	5.xi.	2	3	11.xi.	3	4	20.xi.36	4	5
5	Prior to 29.x.36	1	2	5.xi.	2	3	16 xi.	3	4	26.xi.36	4	5

H. I—(*contd.*)

Date of extra 3rd moult	Number of stripes in IV stage	Date of 4th moult	Number of stripes in extra IV stage	Date of extra 4th moult	Number of stripes in V stage	Date of 5th moult	No. of stripes in Adult	Hopper period	Sex	Remarks
										(*Parents with 5 Eyestripes*)
29.xii.36	5	6	25.i.37	6	7	19.ii.37	7	8	17.iii.37	8	Over 140	Female
7.xii.36	5	6	9.i.37	6	7				19.ii.37	7	Over 115	Female
10.xii.36	5	6	20.i.37	6	7				2.iii.37	7	136	Female
										(*Parents with 6—7 Eyestripes*)
15.xii.36	5	6	11.i.37	6	7				23.ii.37	7		Male
19.xii.36	5	6	4.ii.37	6	7				18.ii.37	7		Female
2.ii.37	5	6	23.ii.37	6	7				16.iii.37	7		Female
2.xii.36	5	6	19.xii.36	6	7				8.ii.37	7		Male
9.xii.36	5	6	11.i.37	5	7				10.iii.37	7		Female

STATEMENT H—II

Showing the Results of Rearings of Hoppers on

Food Plant	Cage No.	Date of Hatching	Date of 1st moult	Number of stripes in early II stage	Date of 2nd moult	Number of stripes in early III stage	Date of 3rd moult	Number of stripes in early extra III stage
1	2	3	4	5	6	7	8	9
Tender Kharzan.	A14	18-11-36	29-11-36	2	8-12-36	3	16-12-36	4
	A15	18-11-36	30-11-36	2	12-12-36	3	21-12-36	4
	A16	18-11-36	4-12-36	2	14-12-36	3	26-12-36	4
	A18	18-11-36	30-11-36	2	11-12-36	3	19-12-36	4
	A19	18-11 36	30-11-36	2	9-12-36	3	20-12-36	4
	A22	18-11-36	27-11-36	2	5-12-36	3	18-12-36	4
	A31	21-11-36	4-12-36	2	12-12-36	3	22-12-36	4
	A32	21-11-36	5-12-36	2	14-12-36	3	26-12-39	4
	A33	21-11-36	5-12-36	2	16-12-36	3	29-12-36	4
	A34	21-11-36	5-12-36	2	16-12-36	3	30-12-36	4
	A35	21-11-36	6-12-36	2	21-12-35	3	31-12-36	4
	A36	21-11-36	7-12-36	2	21-12-36	3	30-12-36	4
	A41	5-12-36	19-12-36	2	30-12-36	3	8-1-37	4
	A42	5-12-36	21-12-36	2	1-1-37	3	12-1-37	4
	A45	5-12-36	22-12-36	2	5-1-37	3	19-1-37	4
	A46	5-12-36	22-12-36	2	31-12-36	3	9-1-37	4
	A55	17-4-37	29-4-37	2	5-5-37	3	11-5-37	4
	A56	17-4-37	27-4-37	2	3-5-37	3	9-5-37	4
	A57	25-4-37	3-5-37	2	9-5-37	3	16-5-37	4
	A58	25-4-37	3-5-37	2	10-5-37	3	16-5-37	4
	A59	25-4-37	1-5-37	2	9-5-37	3	14-5-37	4
	A61	12-7-37	22-7-37	2	28-7-37	3	3-8-37	4
	A62	12-7-37	22-7-37	2	27-8-37	3	1-8-37	4
	A66	21-7-37	29-7-37	2	6-8-37	3	11-8-37	4
	A67	21-7-37	29-7-37	2	3-8-37	3	8-8-37	4
	A68	21-7-37	30-7-37	2	3-8-37	3	9-8-37	4
	A69	11-8-37	19-8-37	2	26-8-37	3	3-9-37	4
	A72	11-8-37	18-8-37	2	25-8-37	3	1-9-37	4
	A73	11-8-37	17-8-37	2	23-8-37	3	30-8-37	4
	A75	14-8-37	21-8-37	2	28-8-37	3	5-9-37	4
	A76	26-9-37	5-10-37	2	12-10-37	3	80-10-37	4
Comparatively old Kharzan.	B9	16-10-36	27-10-36	2	7-11-36	3	18-11-36	4
	B10	16-10-36	26-10-36	2	5-11-36	3	18-11-36	4
	B11	16-10-36	27-10-36	2	7-11-36	3	21-11-36	4
Shoots of Marrand.	C17	24-11-36	8-12-36	2	19-12-36	3	29-12-36	4
	C18	24-11-36	15-12-36	2	21-12-36	3	31-12-36	4
	C19	24-11-36	9-12-36	2	20-12-36	3	30-12-36	4
	C20	24-11-36	8-12-36	2	22-12-36	3	7-1-37	4
	C21	24-11-36	8-12-36	2	16-12-36	3	28-12-36	4
	C22	24-11-36	8-12-36	2	18-12-36	3	30-12-36	4
	C29	8-2-37	17-2-37	2	24-2-37	3	3-3-36	4
	C30	8-2-37	17-2-37	2	25-2-37	3	4-3-37	4
	C31	29-6-37	7-7-37	2	23-7-37	3	31-7-37	4
	C32	29-6-37	8-7-37	2	23-7-37	3	2-8-37	4
	C35	11-8-37	16-8-37	2	23-8-37	3	29-8-37	4
	C36	11-8-37	17-8-37	2	23-8-37	3	29-8-37	4
Jowari seedlings.	D17	8-2-37	17-2-37	2	25-2-37	3	8-3-37	4
	D18	8-2-37	18-2-37	2	27-2-37	3	7-3-37	4
	D24	26-2-37	8-3-37	2	18-3-37	3	28-3-37	4
	D25	26-2-37	9-3-37	2	19-3-37	3	27-3-37	4
	D28	16-3-37	27-3-37	2	4-4-37	3	10-4-37	4
	D29	16-3-37	26-3-37	2	2-4-37	3	12-4-37	4
	D31	25-4-37	2-5-37	2	10-5-37	3	15-5-37	4
	D32	25-4-37	2-5-37	2	10-5-37	3	17-5-37	4

(Mr. R.N. Batra—Ambagh)

different food plants and the corresponding development of eyestripes

Date of Extra 3rd moult	Number of stripes in early IV stage	Date of 4th moult	Number of stripes in early V stage	Date of 5th moult	Number of stripes in early adult stage	Total larval period (Days)	Sex
10	11	12	13	14	15	16	17
		29-12-36	5	17-1-37	6	60	Male
31-12-36	5	14-1-37	6	4-2-37	7	78	Female
		8-1-37	5	29-1-37	6	72	Female
31-12-36	5	13-1-37	6	3-2-37	7	77	Female
		1-1-37	5	21-1-37	6	64	Male
29-12-36	5	8-1-37	6	31-1-37	7	74	Female
		2-1-37	5	20-1-37	6	60	Female
		7-1-37	5	26-1-37	6	66	Male
		11-1-37	5	31-1 37	6	71	Female
		9-1-37	5	26-1-37	6	66	Male
11-1-37	5	23-1-37	6	10-2-37	7	81	Female
8-1-37	5	20-1-37	6	6-2-37	7	77	Male
21-1-37	5	3-2-37	6	20-2-37	7	77	Female
		26-1-37	5	13-2-37	6	70	Male
		2-2-37	5	18-2-37	6	75	Male
21-1-37	5	8-2-37	6	21-2-37	7	78	Female
		18-5-37	5	27-5-37	6	40	Male
		15-5-37	5	24-5-37	6	37	Male
		23-5-37	5	2-6-37	6	38	Female
		23-5-37	5	31-5-47	6	36	Male
		20-5-37	5	30-5-37	6	35	Male
9-8-37	5	16-8-37	6	27-8-37	7	46	Female
6-8-37	5	12-8-37	6	23-8-37	7	42	Female
18-8-37	5	26-8-37	6	9-9-37	7	50	Male
14-8-37	5	22-8-37	6	4-9-37	7	45	Female
		16-8-37	5	27-8-37	6	37	Male
		13-9-37	5	29-9-37	6	49	Male
		19-9-37	6	3-10-37	7	53	Female
9-9-37	5	8-9-37	5	21-9-37	6	41	Female
		13-9-37	5	24-9-37	6	41	Male
		6-11-37	6	23-11-37	7	58	Female
27-10-37	5						
		3-12-36	5	23-12-36	6	68	..
		3-12-36	5	30-12-36	6	75	Male
4-12-36	5	23-12-36	6	19-1-37	7	95	Female
		10-1-37	5	27-1-37	6	64	Male
		11-1-37	5	31-1-37	6	68	Male
		13-1-37	5	3-2-37	6	71	Female
		20-1-37	5	8-2-37	6	76	Male
		9-1-37	5	29-1-37	6	66	Female
		13-1-37	5	3-2-37	6	71	Female
		13-3-37	5	27-3-37	6	47	Male
		14-3-37	5	29-3-37	6	49	Female
7-8-37	5	14-8-37	6	26-8-37	7	58	Male
11-8-37	5	23-8-37	6	8-6-37	7	71	Male
		5-9-37	5	17-9-37	6	37	Male
		5-9-37	5	24-9-37	6	44	Male
		22-3-37	5	5-4-37	6	56	Female
		23-3-37	5	5-4-37	6	56	Male
		8-4-37	5	19-4-37	6	52	Male
		5-4-37	5	17-4-37	6	50	Male
		20-4-37	5	1-5-37	6	46	Male
		22-4-37	5	3-5-37	6	48	Male
20-5-37	5	27-5-37	6	5-6-37	7	41	Female
23-5-37	5	30-5-37	6	9-6-37	7	45	Female

STATEMENT H—II

Showing the Results of Rearings of Hoppers on

1	2	3	4	5	6	7	8	9
	D33	25-4-37	1-5-37	2	7-5-37	3	12-5-37	4
	D34	25-4-37	1-5-37	2	7-5-37	3	13-5-37	4
	D40	2-5-37	9-5-37	2	15-5-37	3	21-5-37	4
	D41	2-5-37	9-5-37	2	14-5-37	3	18-5-37	4
	D43	11-5-37	17-5-37	2	23-5-37	3	29-5-37	4
	D44	11-5-37	17-5-37	2	23-5-37	3	28-5-37	4
	D47	11-5-37	18-5-37	2	25-5-37	3	30-5-37	4
	D48	19-6-37	26-6-37	2	2-7-37	3	8-7-37	4
	D52	11-8-37	18-8-37	2	24-8-37	3	31-8-37	4
	D54	11-8-37	17-8-37	2	23-8-37	3	30-8-37	4
	D55	11-8-37	18-8-37	2	23-8-37	3	30-8-37	4
	D56	11-8-37	17-8-37	2	23-8-37	3	30-8-37	4
Mazoung Shoots	F8	16-10-36	2-11-36	2	22-11-36	3	41-2-36	4
	F9	18-10-36	30-10-36	2	13-11-36	3	28-11-36	4
	F10	14-11-36	27-11-36	2	8-12-36	3	21-12-36	4
	F11	17-11-36	2-12-36	2	17-12-36	3	31-12-36	4
Kohlrabi leaves .	H1	8-2-37	16-2-37	2	25-2-37	3	5-3-37	4
	H2	8-2-37	16-2-37	2	23-2-37	3	4-3-37	4
	H3	8-2-37	17-2-37	2	23-2-37	3	3-3-37	4
	H4	8-2-37	16-2-37	2	23-2-37	3	3-3-37	4
	H5	8-2-37	16-2-37	2	22-2-37	3	2-3-37	4
	H6	8-2-37	17-2-37	2	23-2-37	3	4-3-37	4
Cabbage leaves .	I1	20-4-37	27-4-37	2	1-5-37	3	6-5-37	4
	I2	20-4-37	26-4-37	2	30-4-37	3	7-5-37	4
	I5	20-4-37	26-4-37	2	1-5-37	3	6-5-37	4
	I4	23-4-37	3-5-37	2	9-5-37	3	14-5-37	4
Bosiri (*Indigofera cordifolia*)	J1	14-8-37	20-8-37	2	25-8-37	3	1-9-37	4
	J2	14-8-37	20-8-37	2	25-8-37	3	30-8-37	4
	J3	14-8-37	20-8-37	2	25-8-37	3	30-8-37	4
	J4	24-8-37	29-8-37	2	4-9-37	3	9-9-37	4
	J5	24-8-37	30-8-37	2	4-9-37	3	11-9-37	4
	J6	24-8-37	30-8-37	2	4-9-37	3	11-9-37	4
Maikh (*Tribulus terrestris*)	K1	1-9-37	8-9-37	2	13-9-37	3	20-9-37	4
	K2	1-9-37	8-9-37	2	13-9-37	3	18-9-37	4
	K3	1-9-37	8-9-37	2	13-9-37	3	19-9-37	4
	K4	1-9-37	8-9-37	2	13-9-37	3	19-9-37	4
	K7	4-10-37	12-10-37	2	13-10-37	3	24-10-37	4
Palak .	L1	16-11-37	28-11-37	2	12-12-37	3	12-1-38	4
	L2	16-11-37	28-11-37	2	11-12-37	3	19-12-37	4
	L3	16-11-37	27-11-37	2	8-12-37	3	5-1-38	4
Dranna .	105B	25-4-38	2-5-38	2	6-5-38	3	13-5-38	4
	105C	25-4-38	2-5-38	2	7-5-38	3	14-5-38	4
	105F	25-4-38	6-5-38	2	14-5-38	3	20-5-38	4
	108C	24-7-38	31-7-38	2	6-8-38	3	14-8-38	4
	108D	24-7-38	1-8-38	2	6-8-38	3	14-8-38	4
Ispe-phul .	104B	9-4-38	17-4-38	2	22-4-38	3	30-4-38	4
	104C	9-4-38	17-4-38	2	23-4-38	3	29-4-38	4
	104E	9-4-38	17-4-38	2	24-4-38	3	30-4-38	4
	104H	9-4-38	17-4-38	2	23-4-38	3	29-4-38	4
	107A	24-7-38	30-7-38	2	4-8-38	3	10-8-38	4
	107B	24-7-38	29-7-38	2	4-8-38	3	10-8-38	4
	107C	24-7-38	29-7-38	2	4-8-38	3	10-8-38	4
	107D	24-7-38	30-7-38	2	3-8-38	3	10-8-38	4
Tender Kharzan	A60	29-6-37	8-7-37	2	16-7-37	3	24-7-37	4

Mr. R. N. Batra, Ambagh)—*contd.*

different food plants and the corresponding development of eyestripes

10	11	12	13	14	15	16	17
		26-5-37	5	4-6-37	6	40	Male
		19-5-37	5	28-5-37	6	33	Female
26-5-37	5	31-5-37	6	11-6-37	7	40	Female
25-5-37	5	30-5-37	6	9-6-37	7	38	Female
		3-6-37	5	13-6-37	6	33	Male
		3-6-37	5	13-6-37	6	33	Female
		6-6-37	5	18-6-37	6	38	Female
15-7-37	5	25-7-37	6	4-8-37	7	46	Female
		9-9-37	5	22-9-37	6	42	Female
		6-9-37	5	18-9-37	5	36	Male
		7-9-37	5	18-9-37	6	38	Male
		8-9-37	5	20-9-37	6	40	Female
		23-12-36	5	14-1-37	6	90	Female
		10-12-36	5	31-12-36	6	74	Male
2-1-37	5	20-1-37	6	18-2-37	7	96	Female
		21-1-37	5	19-2-37	6	94	Female
		15-3-37	5	28-3-37	6	48	Male
		16-3-37	5	30-3-37	6	50	Female
		14-3-37	5	28-3-37	6	48	Female
		13-3-37	5	27-3-37	6	47	Male
		11-3-37	5	25-3-37	6	45	Male
		15-3-37	5	29-3-37	6	49	Male
		11-5-37	5	20-5-37	6	30	Male
		13-5-37	5	21-5-37	6	31	Female
		12-5-37	5	20-5-37	6	30	Male
		20-5-37	5	29-5-37	6	34	Female
5-9-37	5	12-9-37	6	25-9-37	7	32	Female
		6-9-37	5	16-9-37	6	33	Male
		6-9-37	5	16-9-37	6	33	Male
15-9-37	5	22-9-37	6	1-10-37	7	38	Female
		19-9-37	5	2-10-37	6	39	Male
		18-9-37	5	1-10-37	6	38	Female
		28-9-37	5	9-10-37	6	38	Female
		26-9-37	5	6-10-37	6	35	Male
		27-9-37	5	8-10-37	6	37	Female
		27-9-37	5	8-10-37	6	37	Female
1-11-37	5	11-11-37	6	28-11-37	7	55	Female
3-2-38	5						
12-2-38	5	25-2-38	6	23-3-38	7	127	Female
		3-3-38	6	28-3-38	7	139	Female
		2-2-38	5	5-3-38	6	109	Male
20-5-38	5						
21-5-38	5	27-5-38	6	5-6-38	7	41	Male
27-5-38	5	29-5-38	6	10-6-38	7	46	Male
		3-6-38	6	13-6-38	7	49	Male
		24-8-38	5	7-9-38	6	45	Male
		22-8-38	5	6-9-38	6	44	Male
		7-5-38	5	19-5-38	6	40	Female
		5-5-38	5	15-5-38	6	36	Male
		7-5-38	5	18-5-38	6	39	Male
		7-5-38	5	19-5-38	6	40	Female
		18-8-38	5	1-9-38	6	39	Female
		17-8-38	5	31-8-38	6	38	Male
		18-8-38	5	1-9-38	6	39	Male
		18-8-38	5	1-9-38	6	39	Female
4-8-37	6	11-8-37	7	22-8-37	8	54	Female

STATEMENT J—1

Effect of Sunlight on the colour of wing bases of the Desert Locust

Abbreviations

Slight . Sl.	Very . V.	Yellow . Yl.	Mauve . M.
Ting . Tg.	Pink . Pk.	Dirty . Dty.	Right wing . Rw.

Particulars of Experiment	Date of Starting	Date of I Examination	Date of II Examination	Date of III Examination	General Results in regard to appearance of colour at base of wings
			PASNI—1935		
EXPERIMENT 1.	8th June 1936.	24th June 1936.	5th July 1936.		Days very bright and sunny during June; July was misty & cloudy
(1) *Right elytron removed* :					
Number of locusts in cage kept in sunshine : Six (2 males & 4 females)	The hind-wings including the wing-bases hyaline.	1. Hind-wings have assumed a light yellow tinge : (1 male missing) wing-base pink or mauve in all on the right side; left wing also pink or mauve in two specimens.	1. Wings light yellow; wing-bases pink or mauve on both sides, but colour deeper on the right side.	.. .. ..	The general body colour of the locust was pinkish on the 8th June, gradually the coloration assumed a darkish blue hue.
(2) *Both elytra removed*:					
Number of locusts kept in cage in the sun : Eight (4 males & 4 females).	do.	2. Wings light yellow in all ; wing-bases pink or mauve on both sides except in one specimen.	2. Both sides pink or mauve except in one.	..	In July, the hind-wiings assumed a deep yellow colour, pink and mauve being lost.

EXPERIMENT II.	4th November 1936.	20th November 1936.	6th November 1936	..	Days mostly sunny and bright except in the mornings.
(1) *Right elytron removed* :					
10 locusts (3 males & 7 females).	Hind-wings hyaline mostly but light yellow in some.	1. Wings light yellow; light pink or mauve in 3 specimens, on right side in one, and on both sides in two.	1. Wings light yellow to yellow; wing-bases light, or deep mauve in most, in one pink turning into mauve, both sides affected.		
(2) *Both elytra removed*:					
10 locusts (4 males & 6 females).	do.	2. Wings light yellow in most; wing-bases pink or mauve on both sides in 3 males.	2 Wings yellow in most ; bases mauve or pink in all and on both sides.		
(3) *Both elytra intact*					
10 locusts (3 males & 7 females). (Control)	do.	3. Wings light yellow in most; wing-bases light mauve in both wings of 2 females.	3. Wings yellow to light yellow; bases light tinge of mauve on both sides in 3 locusts.		
		AMBAGH—1936			
EXPERIMENT I.					
Right elytron removed :	17th June 1936.				
4. locusts, fledged on 17th June 1936, were used. Cage kept in the sun.	Wings fully hyaline.	Examined in July, it was found that there was no development of blue or mauve at the wing-bases, the whole wing having turned yellow.	..	..	There were a few sunny days in June, but by the last week of the month, the weather changed, with the break of the monsoon.

Particulars of Experiment	Date of Starting	Date of I Examination	Date of II Examination	Date of III Examination	General Results in regard to appearance of colour at base of wings
EXPERIMENT II.					
Right elytron removed :	16th September 19	7th/9th October 1936.	15th/21st Oct. 1936.		
5 locusts which became adult on 16th September 1936 were used in the experiment.	Wings fully hyaline.	Mauve or blue tinge distinct at the base of the right hind-wing.	Mauve tinge found also on left wing at the base.	..	Days mostly sunny and bright.
EXPERIMENT III.					
Right elytron removed :	24-28th October 1936	22-27th November 1936	..	..	Days sunny and bright mostly.
6 specimens which became adult between the 24th and the 28th October were used.	Wings fully hyaline.	Pink, mauve or blue tinge was found to have appeared at the base of the right wing.			
		KARACHI—1936			
EXPERIMENT I.	15th June 1936.	10th July 1936.	..	..	
A dozen specimens with hyaline wings were selected from locusts that had recently become adult in cages and had the elytra removed and kept in the sun, enclosed in a wire gauze cage.	Wings fully transparent.	Wings had assumed a light yellow to deep yellow colour. These was no tinge of blue or mauve at the base of the wings.			Days were sunny during the middle of June, but by the last week, it became cloudy and several showers were also recorded early in July

EXPERIMENT II.	10th September 1936.	22nd October 1936.			
60 recently fledged specimens had their right elytra removed. before being enclosed in a cage.	Wings fully hyaline.	About 20 locusts had definitely developed a pink or mauve tinge at the base of the right wings, while the left wings were mostly hyaline.	..	..	Days in September and October were mostly bright, but as the cages were kept in a place surrounded by tall buildings they did not get more than six hours of sun shine on the whole.
EXPERIMENT III.	22nd October 1936	14th December 1936.			
The experiment was repeated in October with 40 newly fledged specimens.	Wings hyaline	A pink or mauve tinge was noticed only in 12 specimens.	..	..	Days during November and December mostly bright but the general temperature lower than in October.

PASNI—1937

(M. L. Roonwal)

SET I.					
1. *Both elytra intact*:	4th November 1936.	12th November 1936.	30th November 1936.	20th December 1936.	
2. males, 7 females.	3 females Sl. Yl., 3 males, 4 females colourless. Wing-bases colourless.	5 females Sl. Yl. 3 males. 1 female colourless. Wing-bases colourless.	3 males. 6 females Yl. In 2 females wing bases V. Sl. M.	1 male, 1 female Sl. Yl; 4 females Yl. In 2 females wing-bases Sl. M.	20%
2. *Right elytron removed*:					
4 males, 6 females.	1 female Sl. Yl. 4 males, 5 females colourless. Wing-bases colourless.	3 females Sl. Yl. 4 males, 2 females colourless. In 2 females wing-bases Sl. M.	3 males. 4 females Sl. Yl. Wing-bases in 1 male Pk. in Rw. 1 male. 3 females Sl. M. and 1 male M. in Rw.	2 males, 4 females Sl. Yl. 1 female Yl. Wing-bases in 2 males and 5 females. M.	80%

Particulars of Experiment	Date of Starting	Date of I Examination	Date of II Examination	Date of III Examination	General Results in regard to appearance of colour at base of wings
3. *Both elytra removed*: 4 males, 6 females.	3 females Sl. Yl. 4 males, 3 females colourless. Wing-bases colourless.	1 male, 4 females Sl. Yl. 2 males, 2 females colourless. Wing-bases in 1 male Pk. 2 males Sl. M.	3 males, 5 females Sl. Yl. 1 female Yl. Wing-bases in 1 male Pk. 2 males 4 females Sl. M.	2 males Sl. Yl. 1 male, 4 females Yl. Wing bases in 1 male Pk. 2 males, 1 females Sl. M.	70%
		Freshly emerged locusts received from Karachi on the 14th April 1937			
SET II.					
1. *Both elytra intact*:	20th April 1937.	11th May 1937	25th May 1937	17th June 1937	
2 males, 3 females.	2 males, 3 females colourless. Wing-bases colourless.	2 females Yl. Wing-bases colourless.	All died.	..	0%
2. *Right elytron removed*:					
2 males, 3 females.	2 males, 3 females colourless. Wing-bases colourless.	2 males, 1 female Sl. Yl. 2 females Yl. Wing-bases: in 1 male Sl. Pk. 2 females Sl. M. (more in Rw) in all.	2 males, 3 females Yl. Wing-bases: in 1 female colourless, 1 male Sl Pk. (more in R W)1 male, 1 female M. (more in Rw) 1 female M. in Rw.	All dead.	80%
3. *Both elytra removed*:					
2 males, 3 females.	1 male, 2 females colourless. Wing-base colourless.	1 male, 2 females Yl. Wing-base in 1 mal Sl. M.	1 male, 2 females Yl. Wing-base in 1 male Sl. M.	All died.	20%

Locusts 1-15 days old introduced on 18th July. 1937.

Set III					
1. *Both elytra intact:*	27th July 1937	6th August 1937	24th August 37	9th September 1937	
12 males, 4 females,	2 males Tg.8, males, 4 females colourless. Wing-bases colourless.	4 males Tg. 2 females Sl. Yl. 1 male Yl. 4 males, 3 females colourless. Wing-bases colourless.	1 female Sl. Yl. 6 males, 2 females Yl. Wing-bases colourless.	1 male Yl. Wing-bases colourless.	0%
2. *Right elytron removed.*					
11 males, 6 females.	1 male, 1 female Tg. 10 males 5 females colourless. Wing-bases colourless.	3 males, 1 females Tg. 7 males, 5 females colourless. Wing-bases in 2 males 2 females Pk. (more in Rw) 1 male Pk. & M. (more in AW) 1 male M. in Rw. only 1 male 2 females M. (more in Rw).	8 males, 2 females Sl. Yl., 2 males 3 females Yl. Wing bases: in 1 male, 1 female M. (more in Rw) 9 males, 2 females M.	10 males, 2 females Yl Wing-bases: in 8 males, 2 females no colour. 2 males S. M. in Rw.	87%
Set IV.					
1. *Both elytra intact:*	15th September 1937	22nd September 1937	30th September 1937	20th October 1937	
13 males 5 females.	4 males Tg. 1 male Sl. Yl. 5 males 4 females colourless. Wing bases in 9 females, 5 females colourless 1 male V. Sl. Pk.	1 male Tg. 4 males 1 female Sl. Yl. 5 males Yl. 1 male. 4 females colourless. Wing-bases; in 10 males, 5 females colourless 2 males Sl. M.	1 male, 1 female Sl. Yl. 6 males 4 females Yl. 4 males Dty. Yl. 1 male colourless. Wing-bases: in 12 males, 4 females colourless 1 male SL. M.	All died	11%
2. *Right elytron cut off:*					
12 males, 6 females	2 males, 3 females Tg. 6 males, 1 female Sl. Yl. 2 males, 2 females Yl.-2 females colourless. Wing bases; in 6 males, 6 females colourless 1 female Pk. (more in Rw) 3 males Pk. & M., 2 males, 1 female M.	3 males Tg. 11 males 2 females Yl. 1 male, 1 female Dty. Yl. Wing-bases: 11 males, 2 females colourless 1 male, 1 female Sl. M. 1 female M. in Rw. 1 female M. (more in Rw).	1 male, 1 female Yl., 8 males, 2 females Dty. Yl. Wing-bases colourless.	All died	33%

Particulars of Experiment	Date of Starting	Date of I Examination	Date of II Examination	Date of III Examination	General Results in regard to appearance of colour at base of wings
3. *Both elytra cut off* : 16 males, 6 females	1 male, 1 female Tg. 9 males, 6 females Yl., 1 female colourless. Wing-bases : in 6 males, 7 females colourless 2 males, 1 females Pk. 1 male Pk. & M., 1 male Sl. M.	1 male Tg. 12 male Yl. 2 females Dty Yl. Wing bases ; in 11 males, 3 females colourless 1 male V. Sl. M.	9 males 2 females Dty. Y Wing bases colourless.	All died	23%
Set V.		*Colourless locusts of 2-3 weeks old introduced on the 6th October*			
1. *Both elytra intact* :	17 October 1937	22nd October 1937	2nd November 1937		
3 males, 6 females.	1 male, 2 females Tg. 1 male, 4 females colourless. Wing-bases : in 2 males, 5 females no colour 1 female Sl. Pk.	1 male, 2 females Tg. 2 males , 3 females Sl. Y. Wing-bases colourless.	3 males, 6 females Yl. Wing-bases colourless.	..	11%
2. *Right elytron cut off* : 4 males, 7 females.	2 males, 2 females Tg. 2 males 4 females colourless. Wing bases colourless.	2 males, 3 females Sl.. Yl. 2 males 2 females Yl. Wing-bases in 1 male Pk. in R. 1 female Sl. M. in R.	4 males, 3 females Yl 3 females Dty. Yl. Wing-bases colourless.	..	13%
3. *Both elytra cut off.* 4 males, 7 females	1 male, 5 females Tg. 3 males, 2 females colourless. Wing bases	4 males, 2 females Sl. Yl. 3 females Yl. 1 female colourless.	2 males, 3 females Yl. 3 females Dty. Yl Wing-bases: 6	..	27%

	in 3 males, 5 females no colour 1 male 1 female Sl. M.	Wing—bases : in 1 male Pk. & M. 1 male, 1 female Sl. M.	1 females no colour. 1 male Pk. & M 1 male Sl. M.		
		KARACHI—1937 (Dr. S. Mukerji—Karachi)			
Set. I. 12 Fresh adults with the hind-wings colourless.	3rd April	5th April 9 with a bluish tinge on the veins of hind-wings of both sides.	7th April 4 developed sight pinkish tinge at the bases of both hind-wings.	14th April Yellowish tingue began to appear in the 8 specimens.	75% Days sunny; exposure to sunshine from about 9 A.M. to 2 P.M. (Approximately).
Set II.					
1. 12 Fresh adults with the hind-wings sttached together over the back.	4th May	7th May 2 with bases of veins in both wings pinkish.	11th May 3 with a few venis pinkish, 1 bluish at the bases of veins.	18th May Hind-wings with a pale yellow tinge.	33% Occasionally cloudy in the morning.
2. 12 Fresh adults with right elytron removed.	6th May	11th May 1 with hind-wing pale yellowish, rest hyd-line.	18th May 2 with faint pink at the base of exposed hind-wing. No appreciable colour on the uncut hind-wing 3 with light blue at the bases of veins. Rest yellowish.	26th May Hind-wings with a yellowish tinge. 2 with veins of the uncut side bluish.	42% Do.
Set III. 12 Fresh adults with right elytron removed kept in a small rearing cage.	23rd August	8th September 1 with veins bluish in both hind-wings.	16th September 10 with light bluish-veins or yellow or hyaline background in both the wings-Depth of colour in cut wing mauve.	21st September Almost all the hind-wings with bluish veins on both wings. General coloration of the hind-wing yellowish.	100% Mostly sunny.

Particulars of Experiment	Date of Starting	Date of I Examination	Date of II Examination	Date of III Examination	General Results in regard to appearance of colour at base of wings.
2. 6 Fresh adults with elytron intact kept in a small hand cage to produce the effect of crowding	23rd August	13th September 1 with bluish veins on a yellowish background on both wings.	21st September 2 with bluish veins on both the wings with hyaline or yellowish background.	24th September Most of the specimens with yellowish hind-wings; the colour of the hind-wings seem to be disappearing.	22%
Set IV.					
1. 12 Fresh adults with right elytron removed.	16th October	28th October 4 with a bluish tinge on the veins. In 2 veins bluish on both sides. Intensity of colour more on cut side. Rest pale yellow or hyaline.	8th November 2 with light mauve at base or on veins. 6 with bluish veins on both wings, intensity of colour more on cut side. Ground colour yellowish in general.	16th November 9 with bluish veins including 1 with mauve at base. Almost all the hindwings developed yellowish tinge.	76%
2. 6 Fresh adults with elytron intact kept in a small hand cage.	16th October	8th November 2 with pale bluish on veins both wings. Rest pale yellow.	16th November 5 with bluish on veins mostly pale yellow background.	20th November Yellowish ground colour deeper.	83%

STATEMENT J—II

Effect of Sunlight on the Coloration of Hind-wings of Schistocerca—Ambagh 1937.

(Mr. R. N. Batra)

Particulars of Experiments	Date of Final moult	Date of appearance of pink mauve or blue tinge at the base of *right* hind-wings	Length of time in days	Date of appearance of pink mauve or blue tinge in the *left* hind-wings	Length of time in days	Remarks
Set I.						
Covered with paint & kept in sunlight.						
1. A single locust with right fore-wing removed and the *left covered over with black paint.*	21-11-36	16-12-36	25	No colour appeared	.	Found dead on 13-1-37. 100%
2. Do	25-11-36	18-12-36	23	No colour developed	..	Found dead on 5-1-37.
3. Do	27-11-36	18-12-36	21	No colour developed	..	Found dead on 19-2-37.
Set II.						
Painted black & kept in sunlight.						
1. A single locust with both right and left elytron painted black.	23-11-36	No pink mauve or blue colour developed.	..	No pink mauve or blue colour developed.	..	Found dead on 6-1-37. 0%
2. Do	27-11-36	Do.	..	Do	..	Found dead on 11-3-37.

Particulars of Experiments	Date of Final moult	Date of appearance of pink, mauve or blue tinge at the base of *right* hind-wings	Length of time in days	Date of appearance of pink, mauve or blue tinge in the *left* hind-wings	Length of time in days	Remarks
SET III.						
In boxes shut off from light.						
1. Two females and three males (two with right elytra removed, one with both elytra removed and two with both elytra intact). *Kept in boxes shut off from sunlight.*	18-10-37 21-10-37	No pink, mauve or blue developed.	..	No pink, mauve or blue developed.	..	Wings gradually turning yellow.
2. With right elytron removed. *Kept in a box shut off from sunlight.*	19-10-37	No pink, mauve or blue developed.	..	Do	..	Wings gradually becoming yellow.
3. With right elytron removed. *Kept in a box shut off from sunlight.*	21-10-37	Do	..	Do	..	Found dead on 30-11-37. 6%
4. With both the elytra removed. *Kept in a box cut off from sunlight.*	21-10-37	Do	..	Do	..	Wings turning yellow.
SET IV.						
Elytra removed. Kept in sunlight.						
1. A pair with the right elytron of each removed. *Kept in sunlight.*	17-10-37 18-10-37	On 16-11-37 On 14-11-37	30 days & 27 days respectively	25-11-37 22-11-37 respectively	39 days & 35 days respectively	Pink colour in the left hind wing developed 9 days after its first appearance in the right hind-wing. 100%

2. A male with eltrone removed. *Kept in sunlight.*	17-10-37		22	14-17-37	28	Pink colour in the left hind-wing developed 6 days after it was first noticed in the right hind-wing. 100%.
3. A female with both elytra intact. *Kept in sunlight.*	19-10-37	16-11-37	23	15-1-47	28	Pink colour in both the wings appeared simultaneously. 100%

GMGIPND—MS—103 I.C. of A.R.—19-3-58—505.

U. A. S. BANGALORE
UNIVERSITY LIBRARY.
28 JAN 1974
ACC NO. G 4638
CL. NO.

25 MAR 1974
Released On.....
UNIVERSITY OF AGRICULTURAL SCIENCES
UNIVERSITY LIBRARY
BANGALORE-24

This book should be returned on or before the date mentioned below; or else the Borrower will be liable for overdue charges as per rules from the DUE DATE.

Cl. No. 595.726 Ac. No. 4638
RAM

16 JUL 1977
690/6
21 OCT 1988
209/75
15 JUL 1995
1503/57

UAS LIBRARY GKVK
G-4638